

## APPENDIX A – FIGURE AND DIAGRAMS

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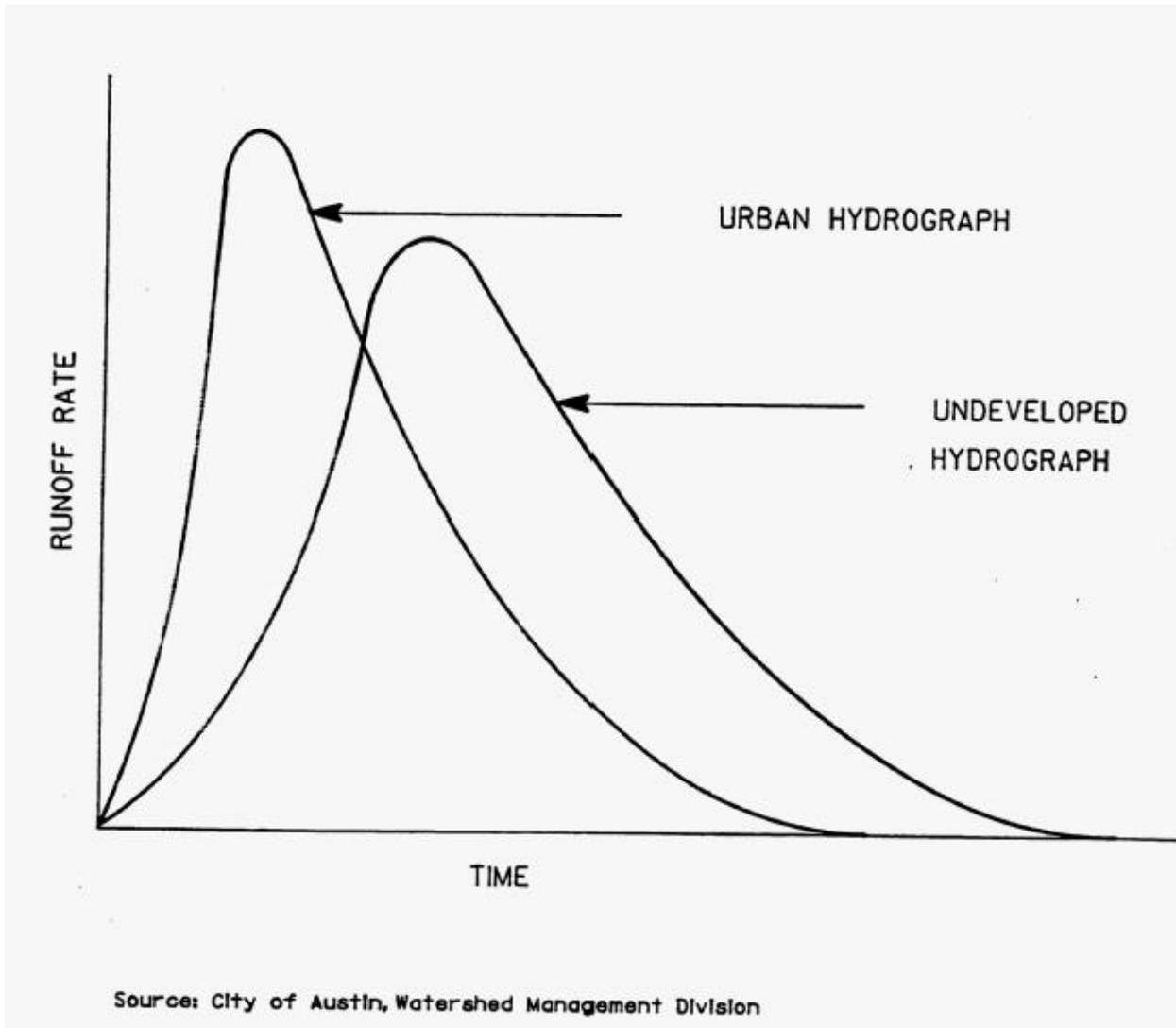


Figure 2-1: Effects of Urbanization on Flood Hydrograph

RAINFALL FREQUENCY-INTENSITY-DURATION CURVES  
(S.D.H. & P.T.-BELL COUNTY)

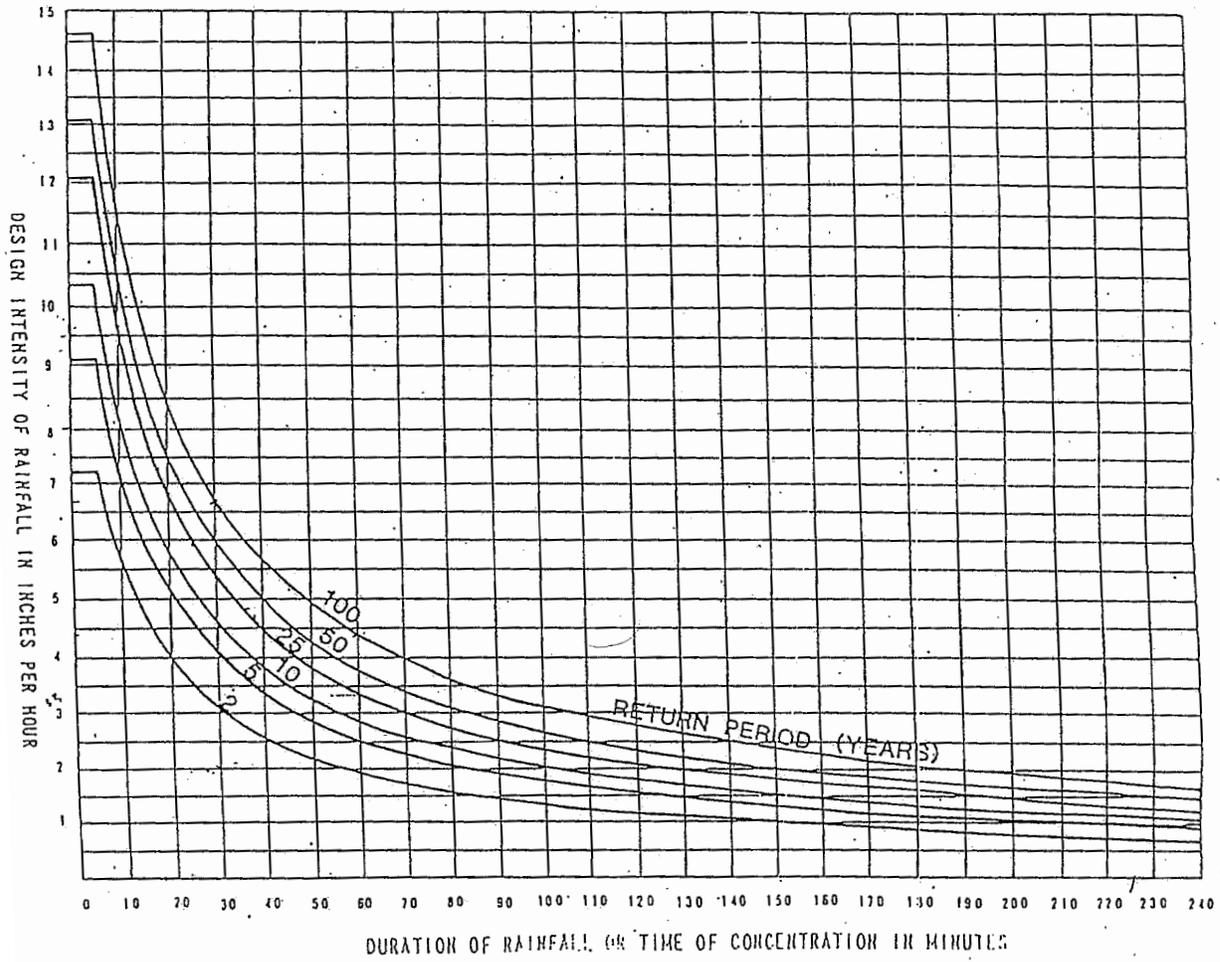
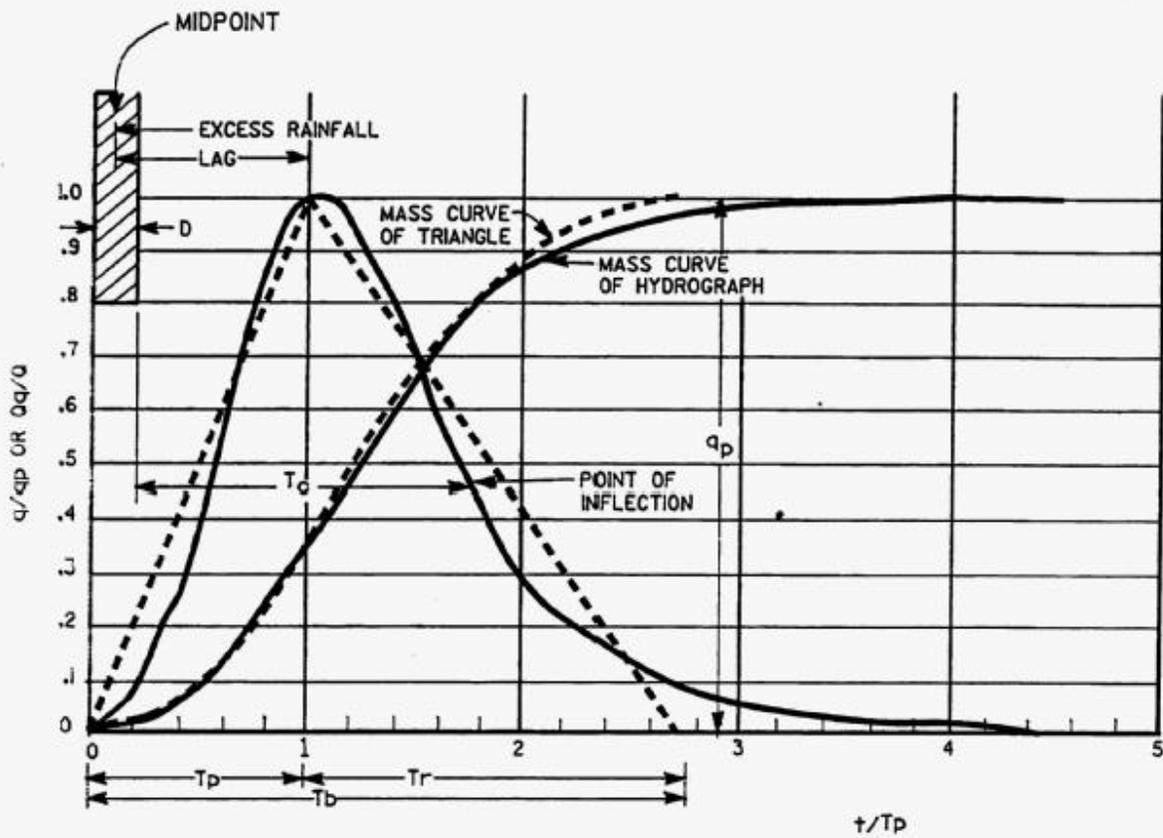


Figure 2-2: Intensity Duration Frequency Curve for Bell County, Texas



Source: U.S. Soil Conservation Service, "Hydrology Section 4,"  
National Engineering Handbook, (NEH-4), 1972.

Figure 2-3: Dimensionless Curvilinear Unit Hydrograph and Equivalent Triangular Hydrograph

FIGURES FROM SECTION 3

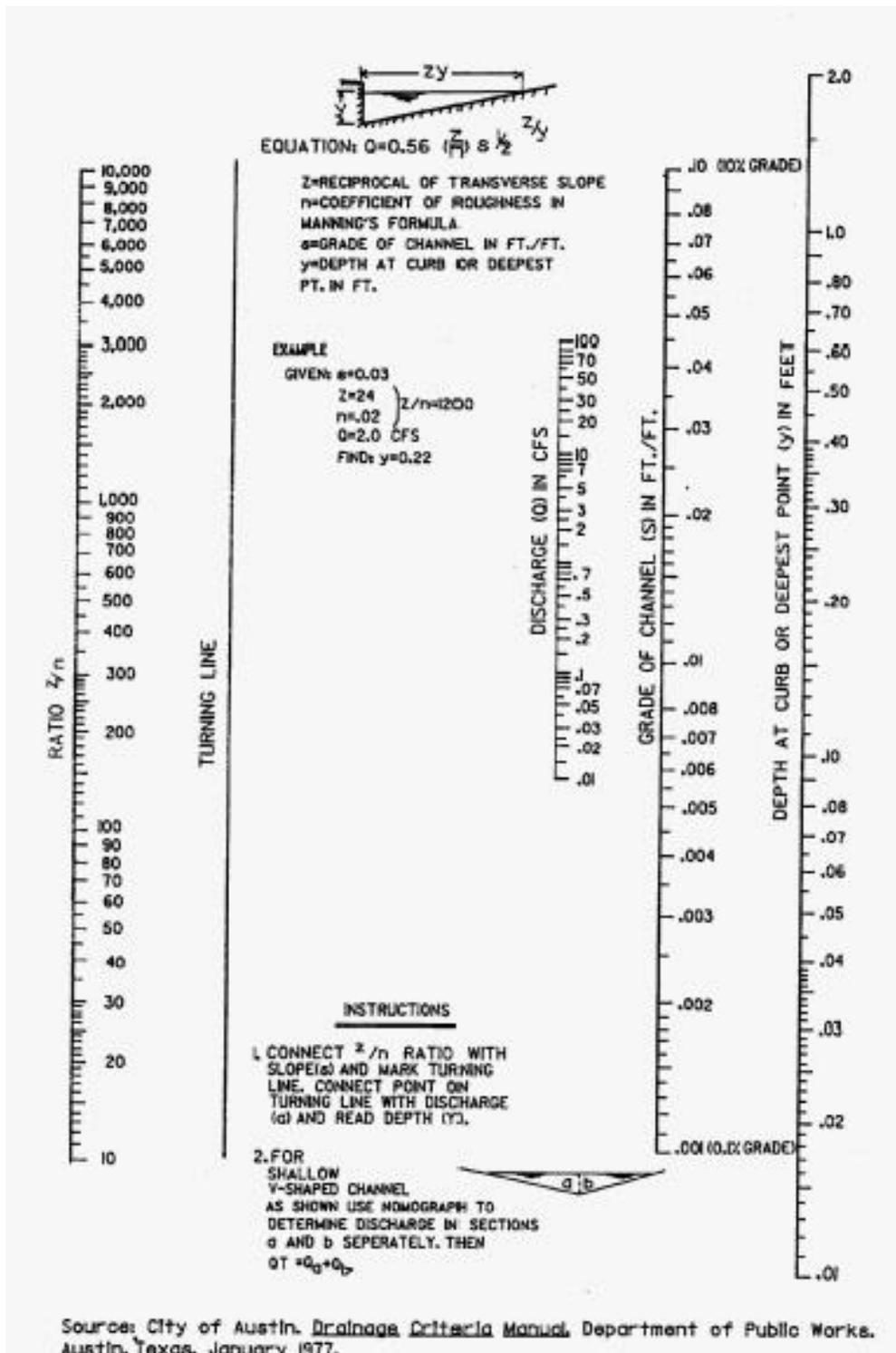


Figure 3-1: Nomograph for Flow in Gutters

FIGURES FROM SECTION 4

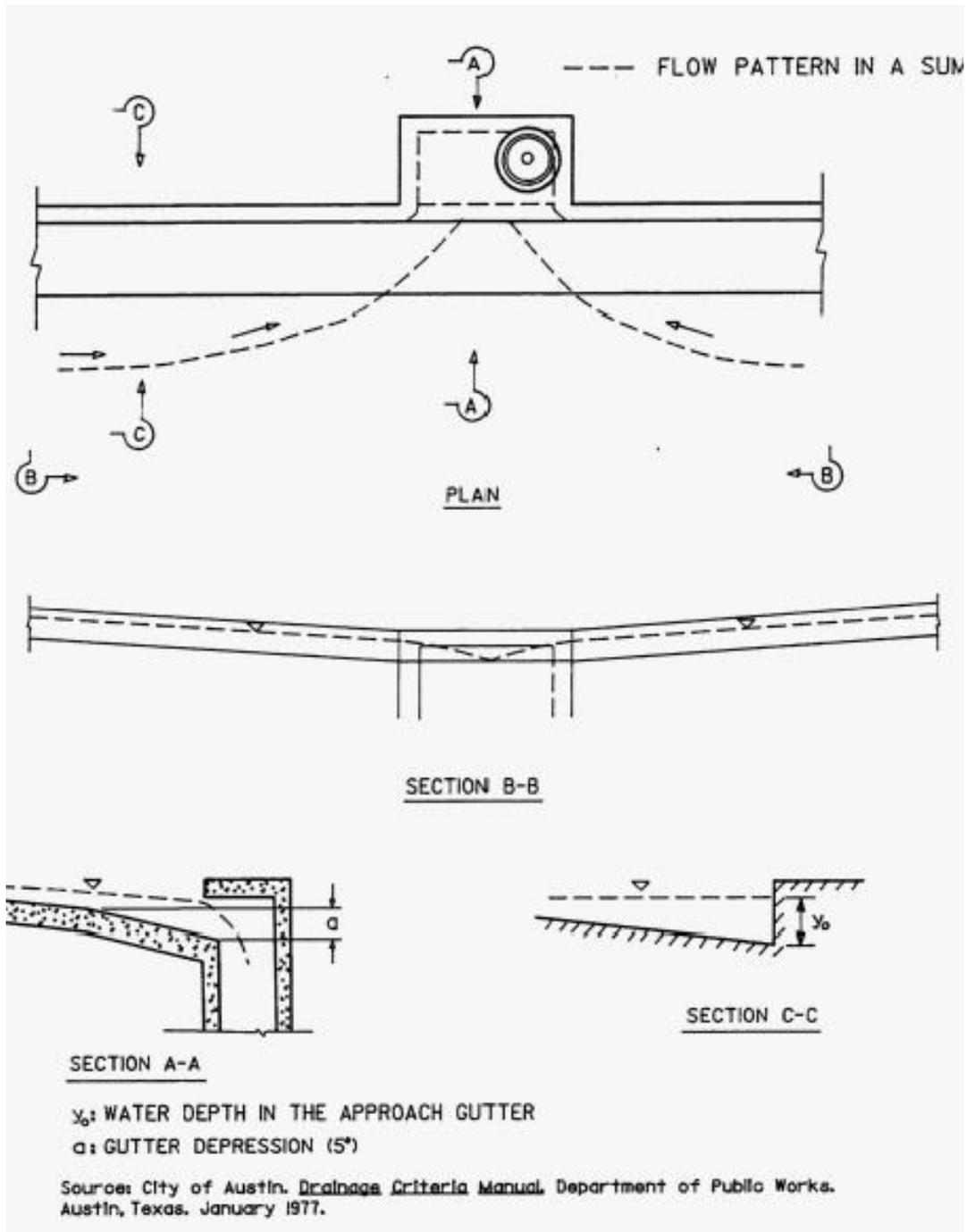


Figure 4-1: Curb Opening Inlet in a Sump (Type S-1)

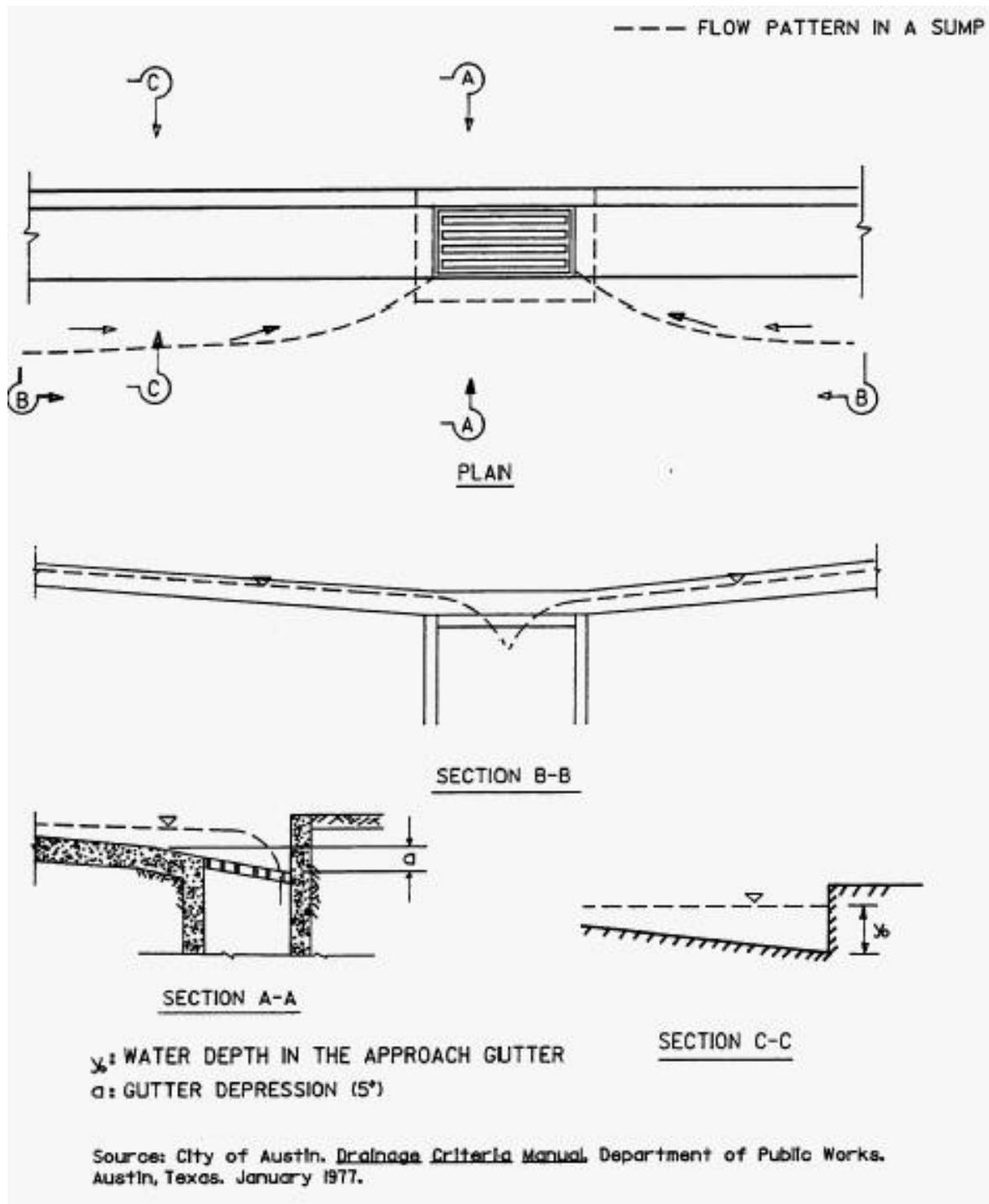


Figure 4-2: Grate Inlet in a Sump (Type S-2)

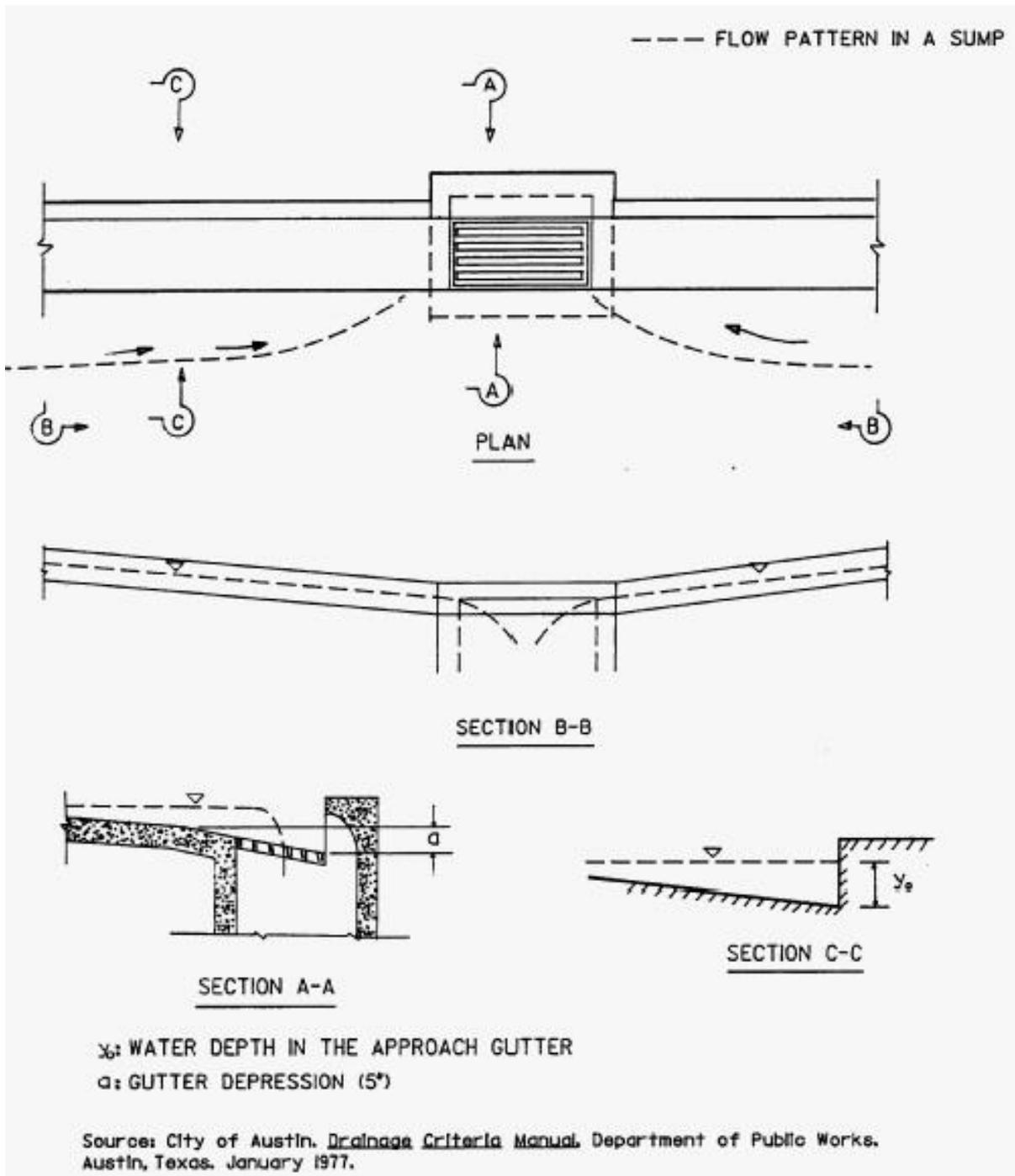


Figure 4-3: Combination Inlet in a Sump (Type S-3)

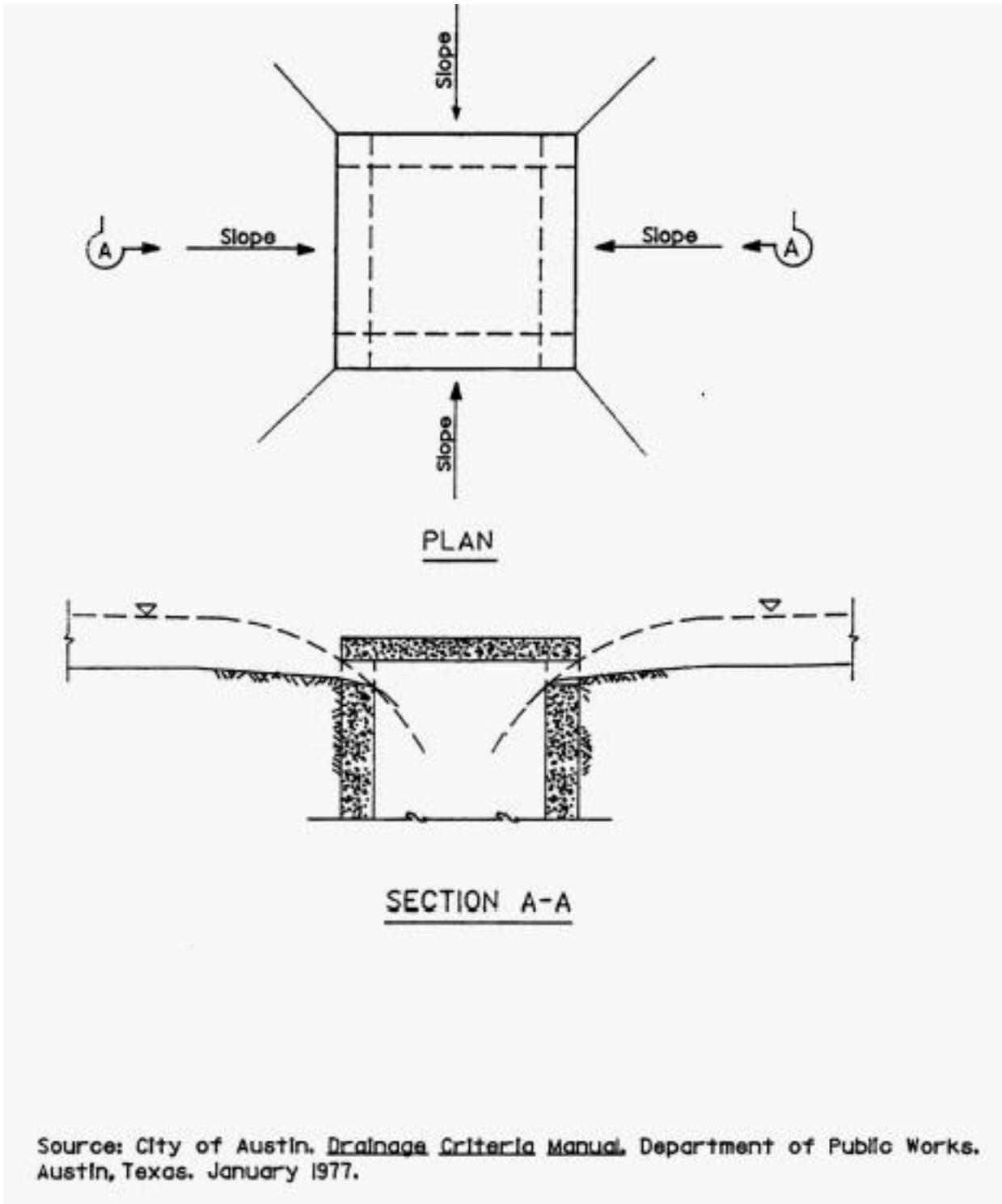


Figure 4-4: Area Inlet Without Grate (Type S-4)

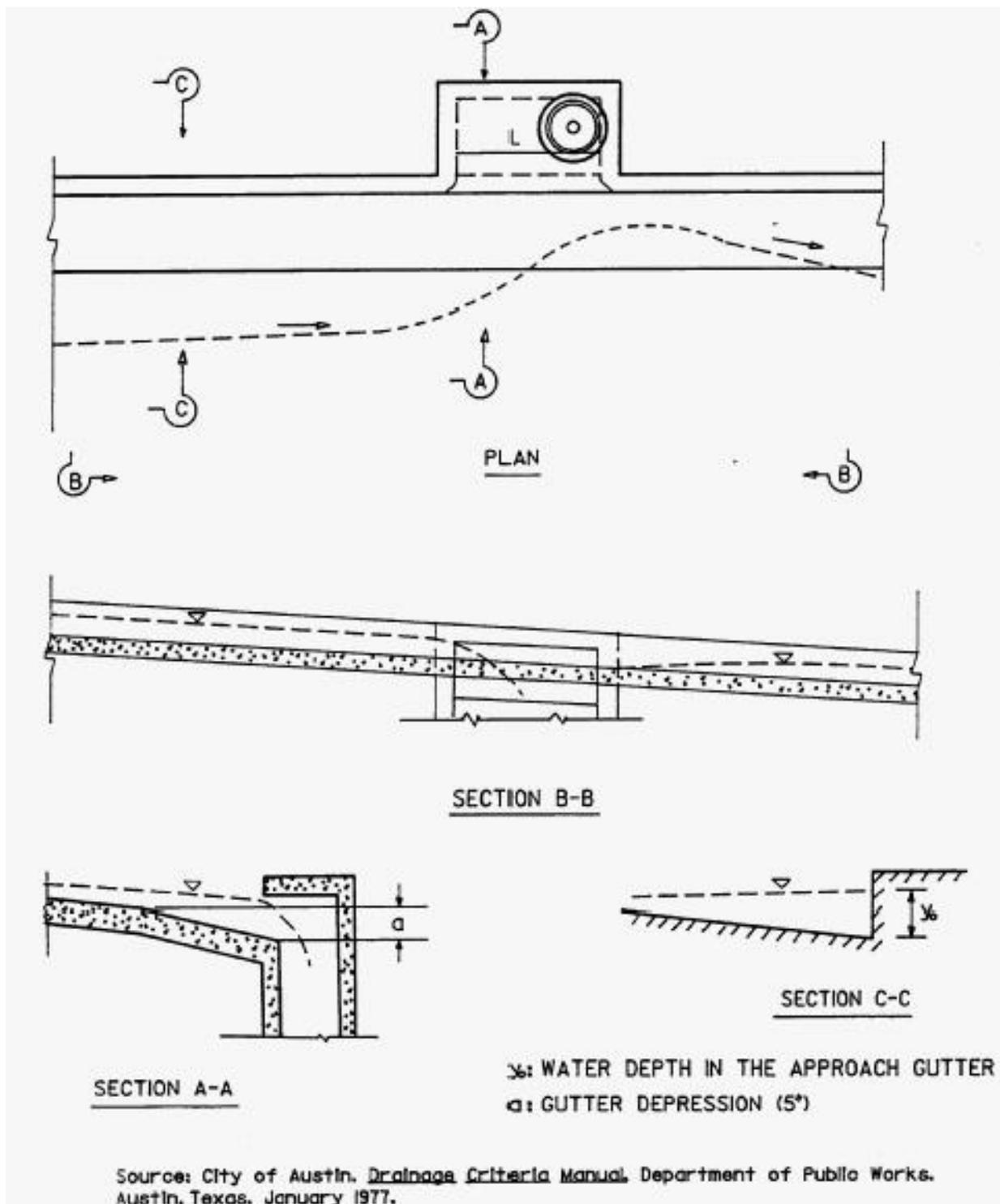


Figure 4-5: Curb Opening, Inlet on Grade (Type G-1)

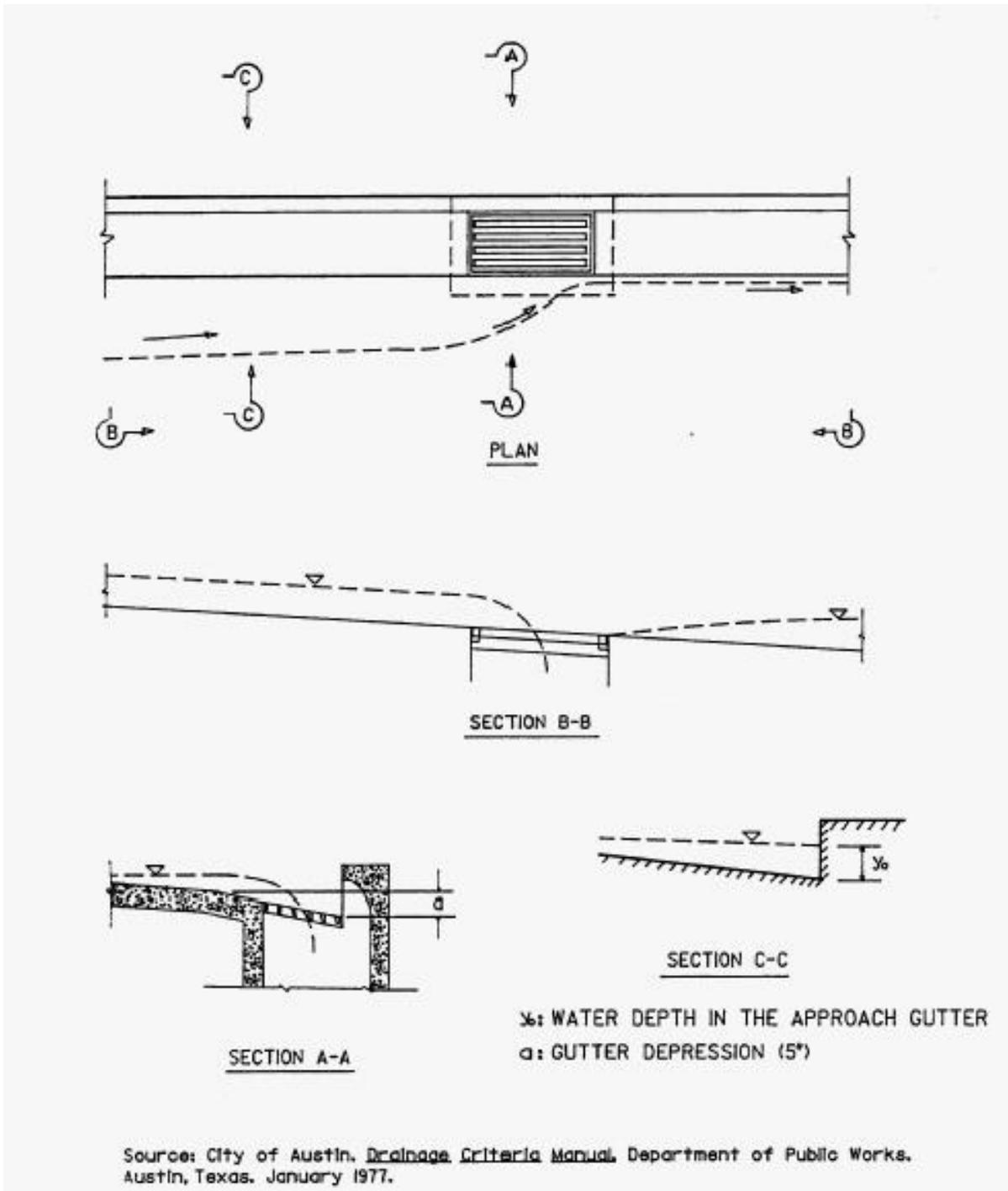


Figure 4-6: Grate, Inlet on Grade (Type G-2)

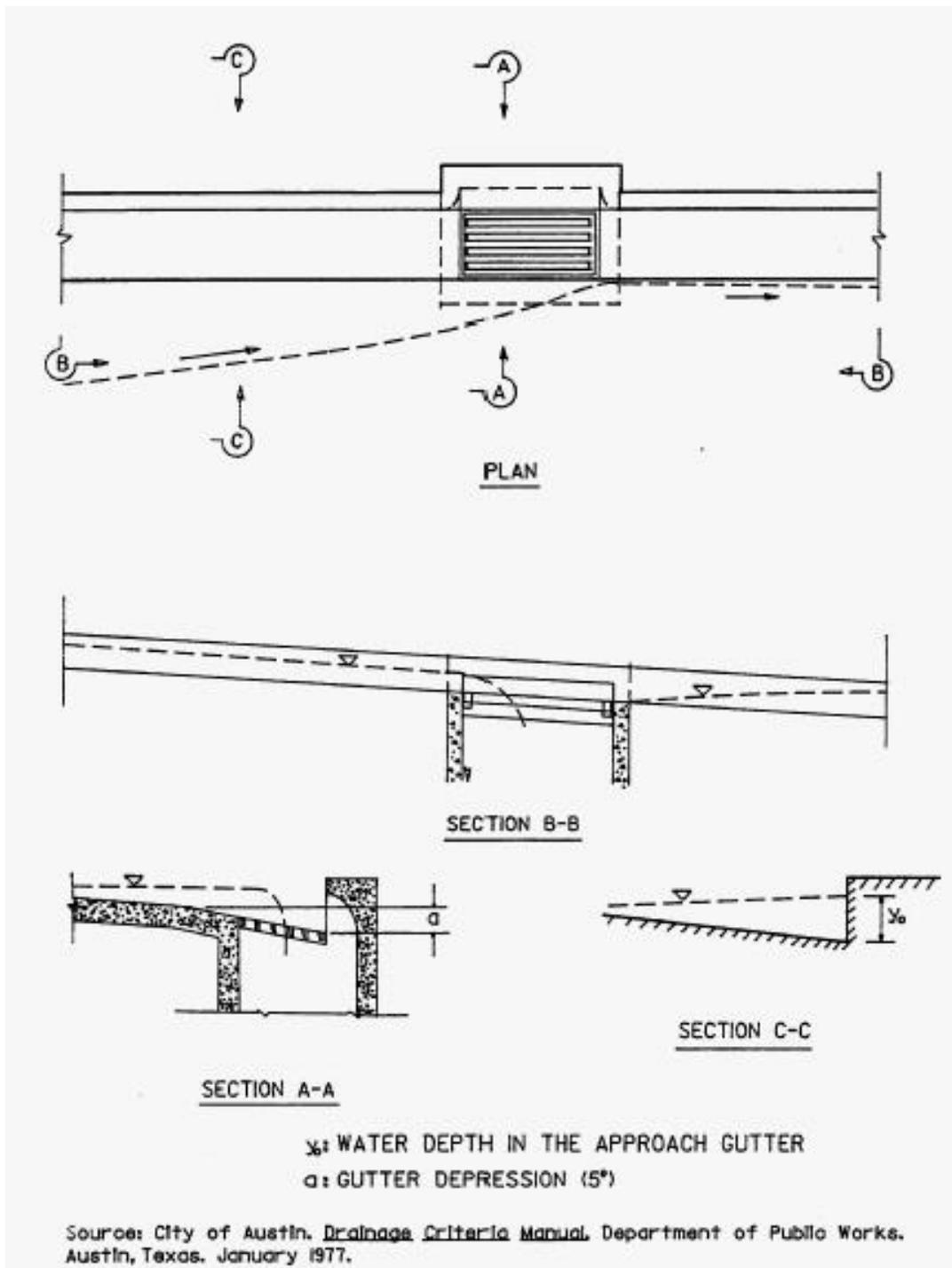
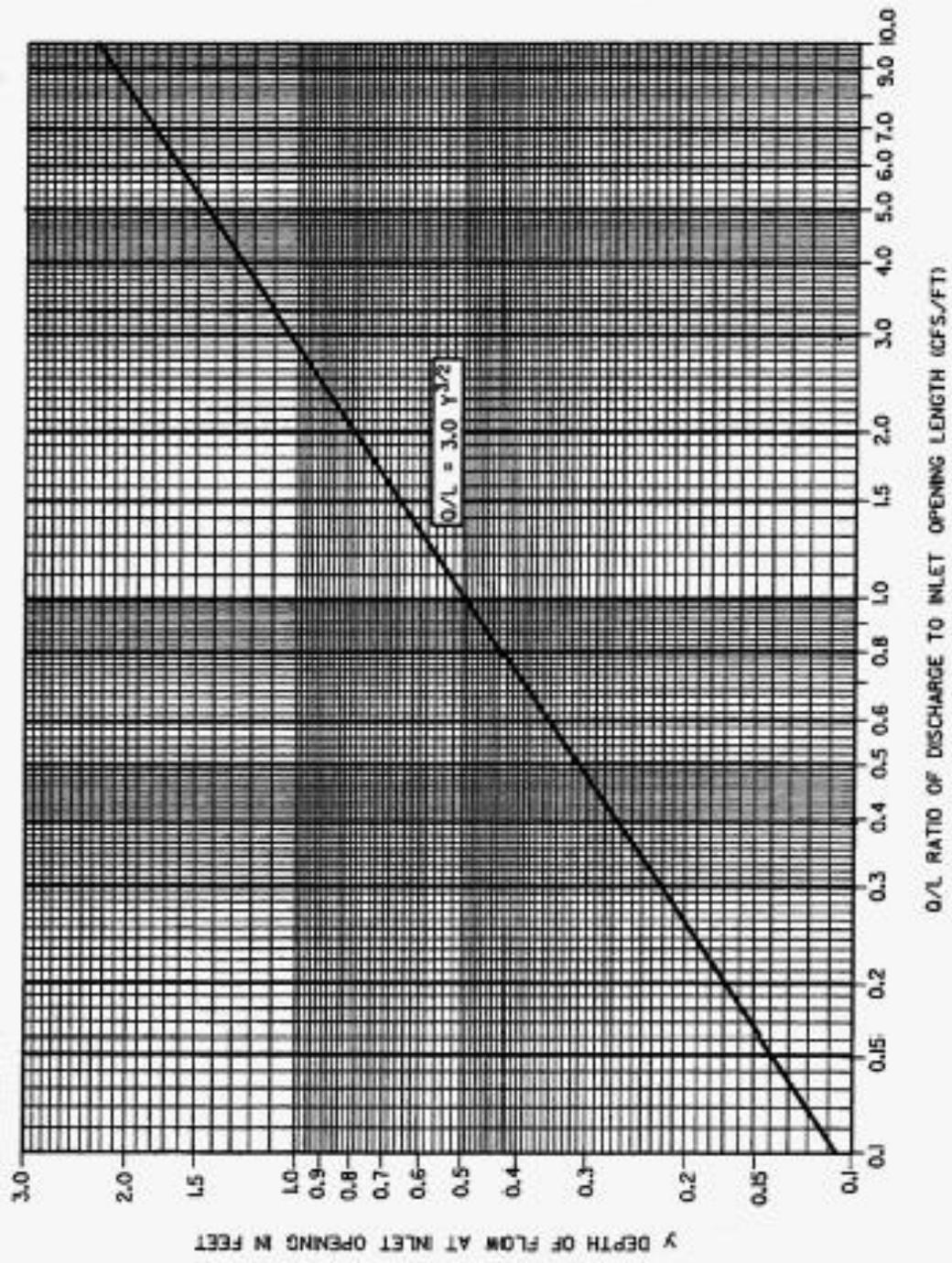


Figure 4-7: Combination Inlet on Grade (Type G-3)



Source: City of Austin, *Drainage Criteria Manual*, Department of Public Works, Austin, Texas, January 1977.

Figure 4-8: Inlet Capacity for Type S-1 and S-3

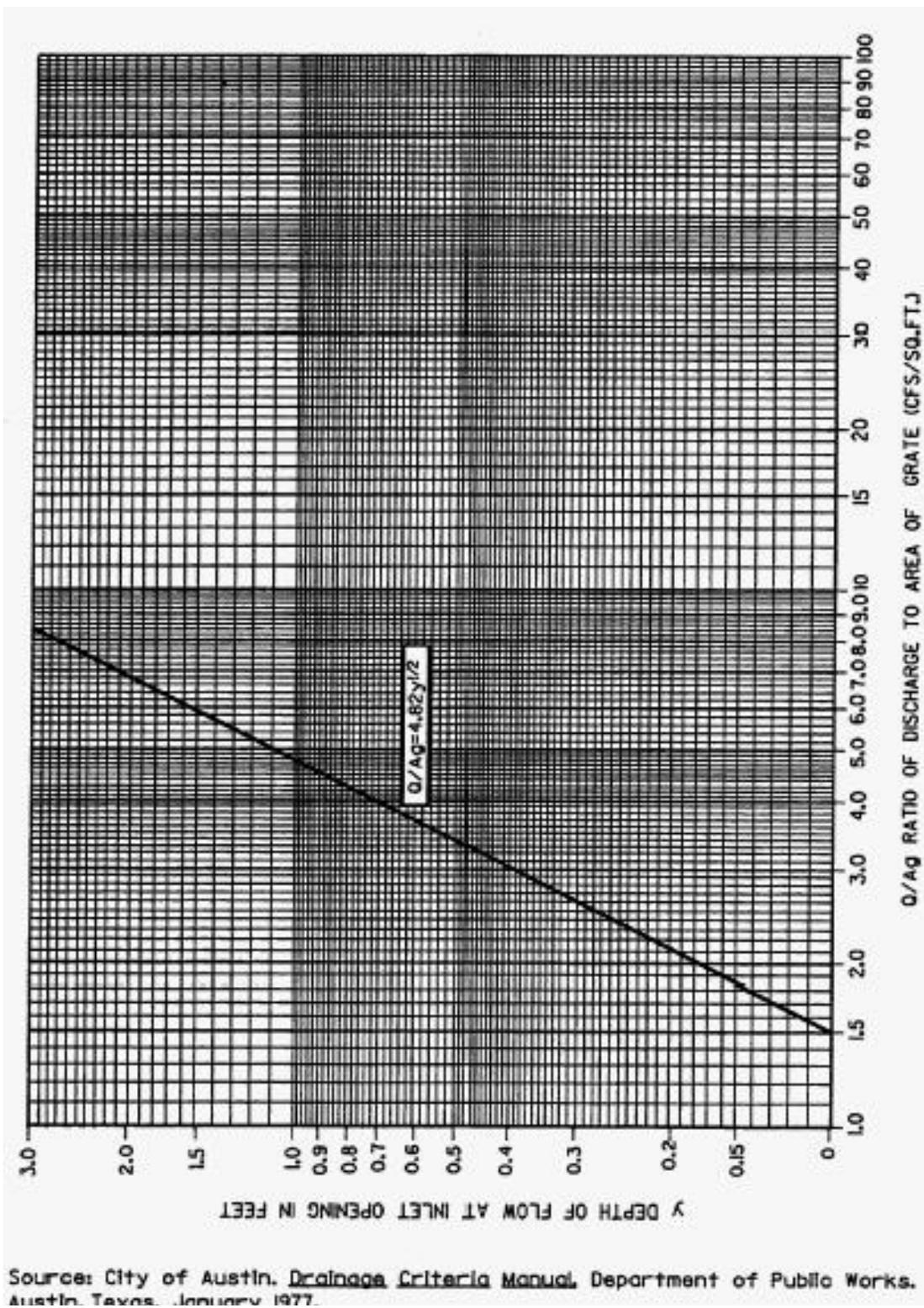
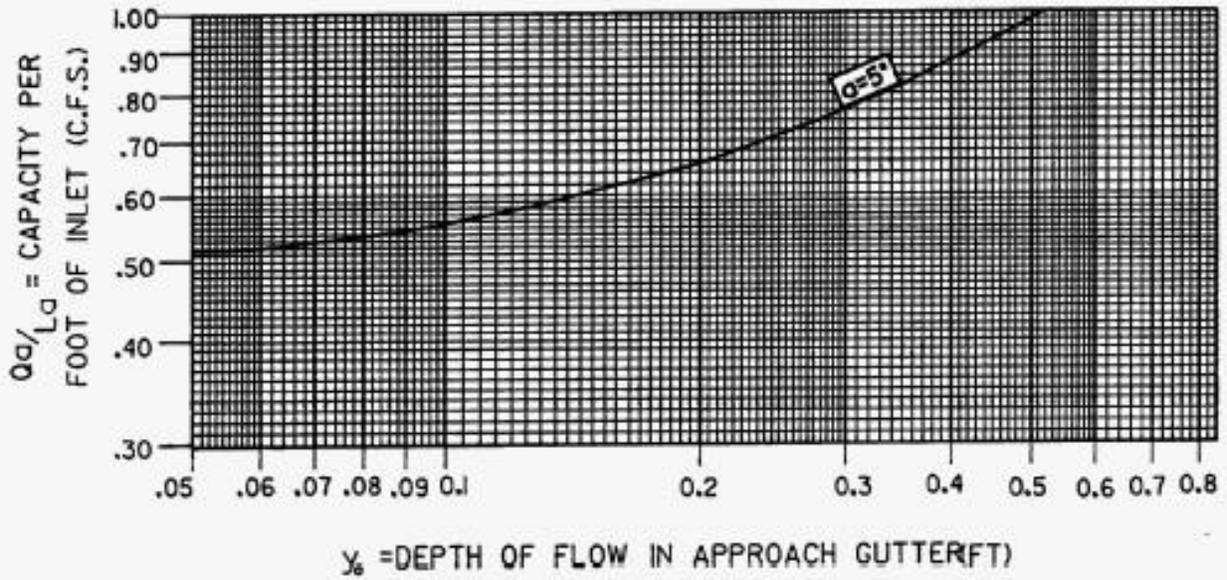


Figure 4-9: Inlet Capacity for Type S-2



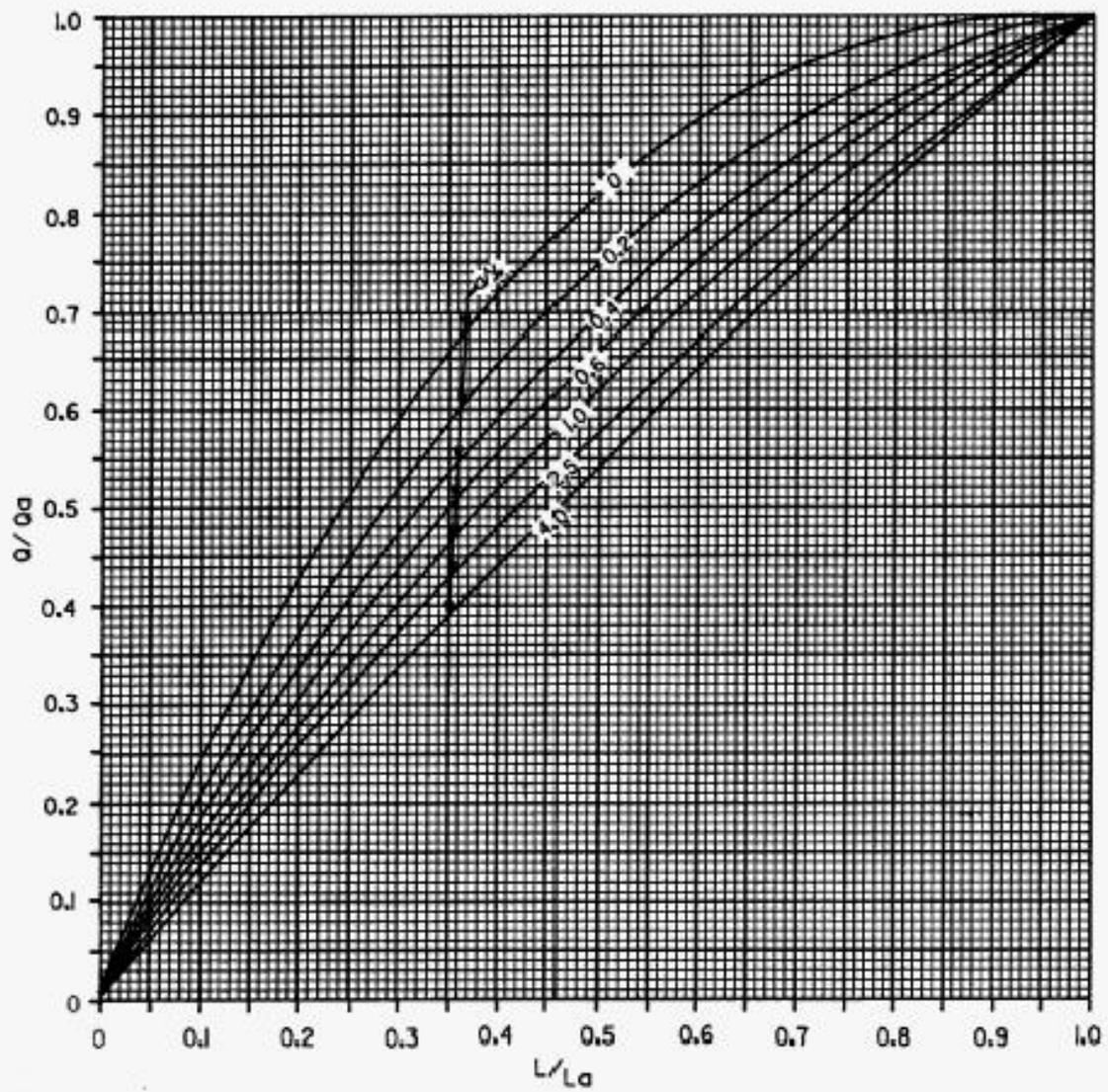
$$Qa/La = 0.7 \left[ \frac{1}{H_1 - H_2} \right] \left[ (H_1)^{5/2} - (H_2)^{5/2} \right]$$

$$H_1 = a + y_0$$

$$H_2 = a = \text{GUTTER DEPRESSION}$$

Source: City of Austin, Drainage Criteria Manual, Department of Public Works, Austin, Texas, January 1977.

Figure 4-10: Capacity for Inlets on Grade



$L$  = LENGTH OF CURB OPENING (FT.)  
 $L_a$  = LENGTH OF CURB OPENING FOR 100% INTERCEPTION (FT.)  
 $Q$  = FLOW INTERCEPTED BY INLET OF LENGTH "L" (C.F.S.)  
 $Q_a$  = TOTAL FLOW IN APPROACH GUTTER (C.F.S.)  
 $a$  = GUTTER DEPRESSION (FT.)  
 $y_a$  = DEPTH OF FLOW IN APPROACH GUTTER

Source: City of Austin, Drainage Criteria Manual, Department of Public Works, Austin, Texas, January 1977.

Figure 4-11: Ratio of Intercepted to Total Flow for Inlets on Grade

FIGURES FROM SECTION 5

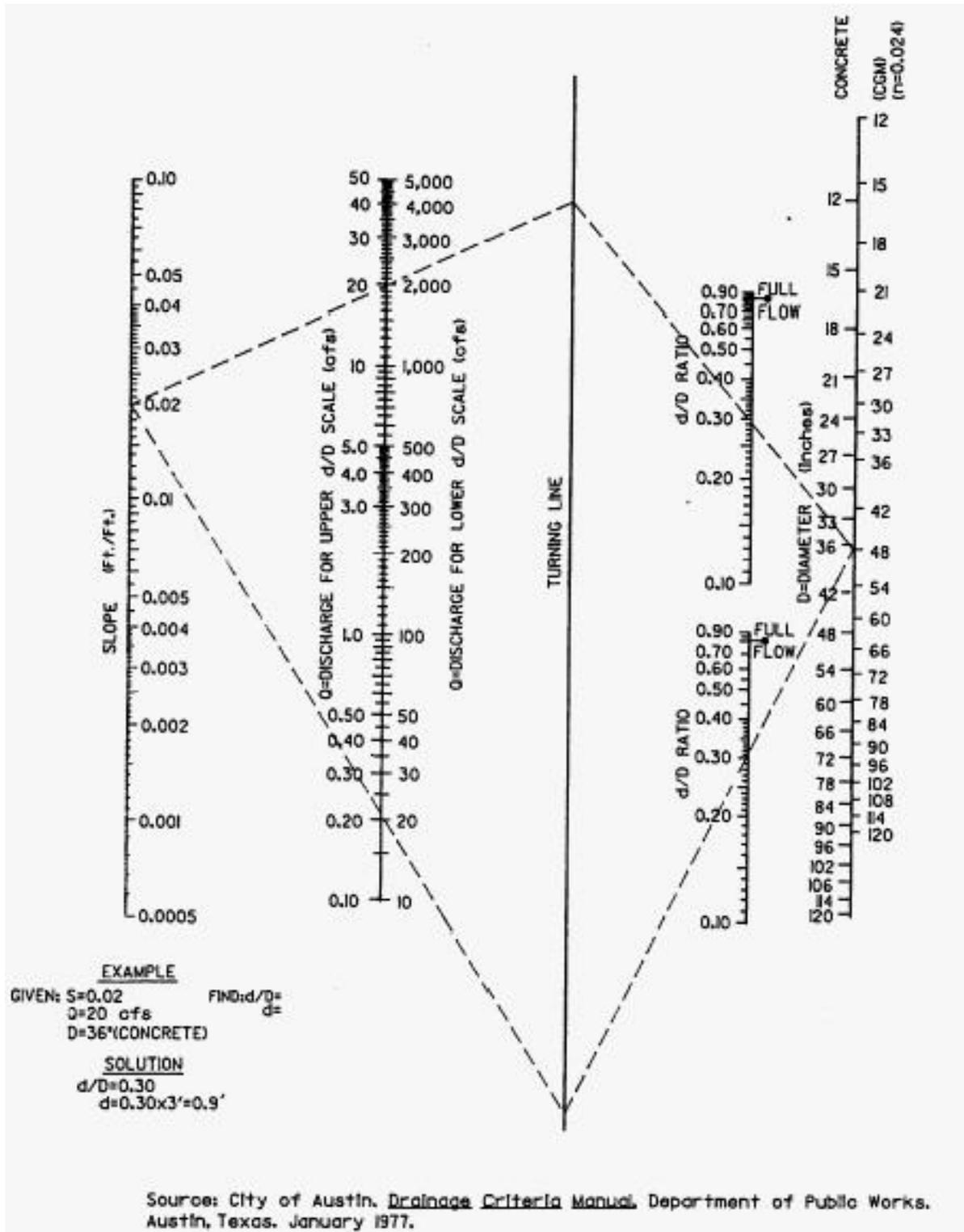
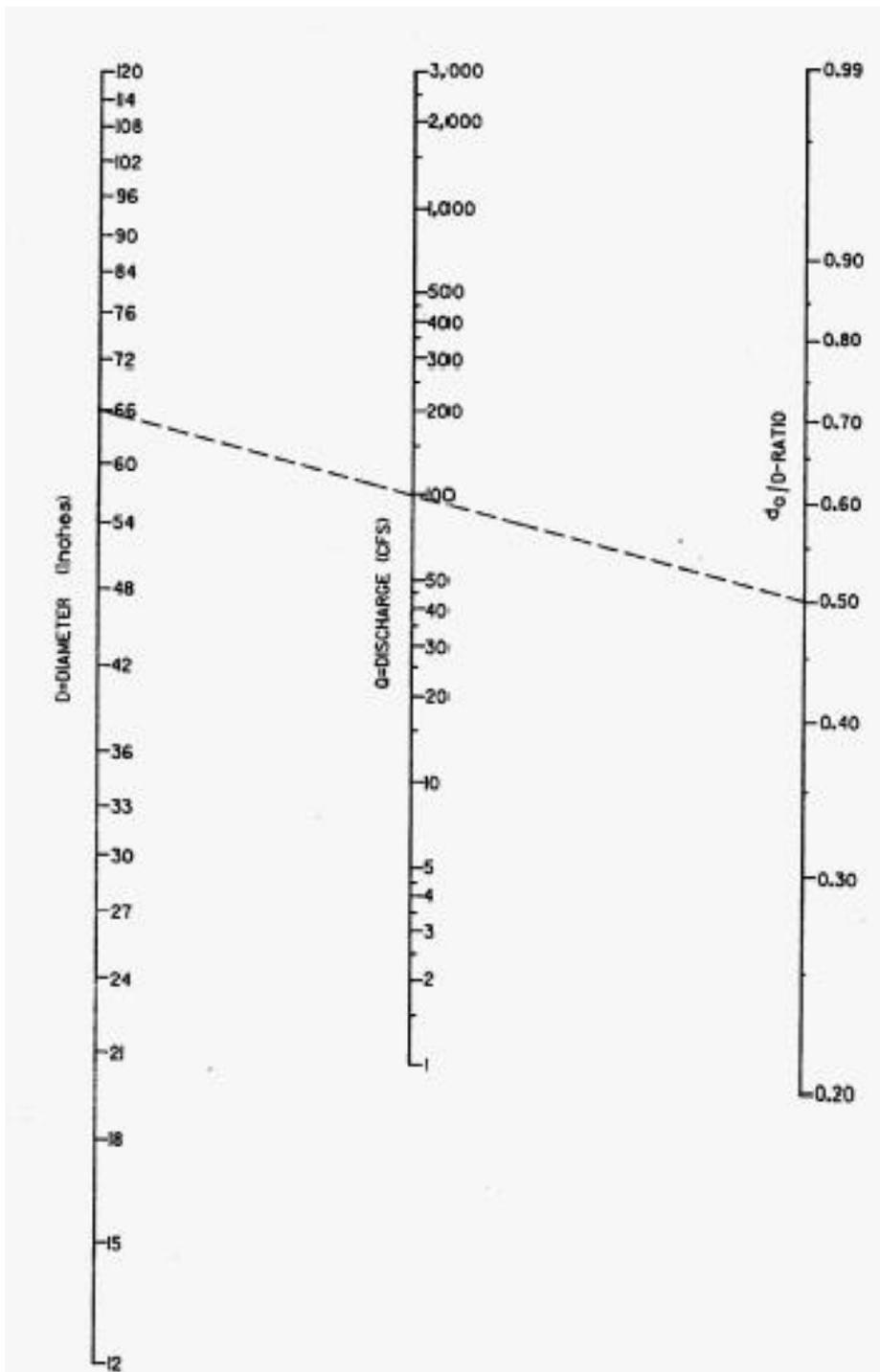
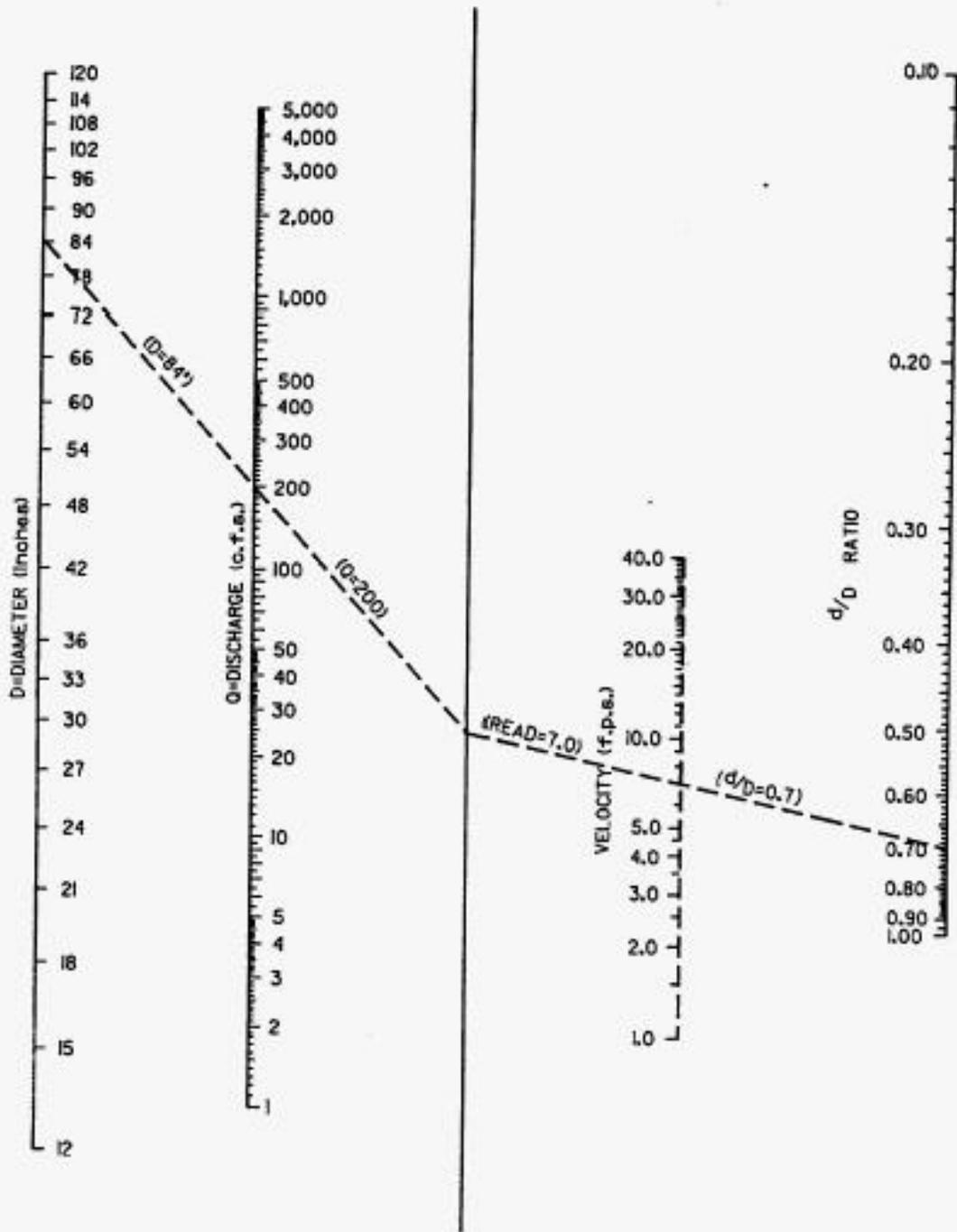


Figure 5-1: Uniform Flow for Pipe Culverts



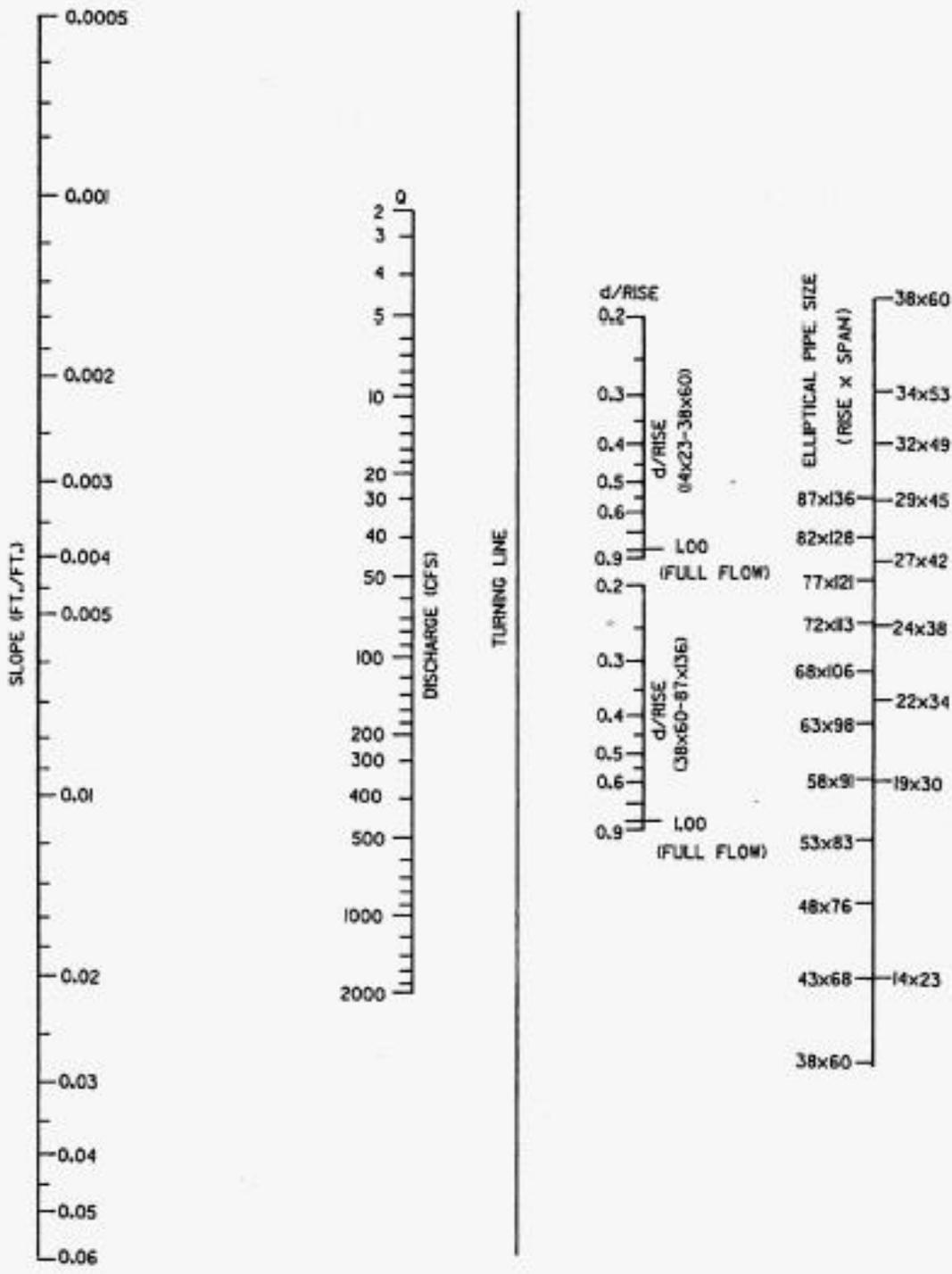
Source: City of Austin, *Drainage Criteria Manual*, Department of Public Works, Austin, Texas, January 1977.

Figure 5-2: Critical Depth of Flow for Circular Conduits



Source: City of Austin, Drainage Criteria Manual, Department of Public Works, Austin, Texas, January 1977.

Figure 5-3: Velocity in Pipe Conduits



Source: City of Austin, Drainage Criteria Manual, Department of Public Works, Austin, Texas, January 1977.

Figure 5-4: Uniform Flow for Concrete Elliptical Pipe

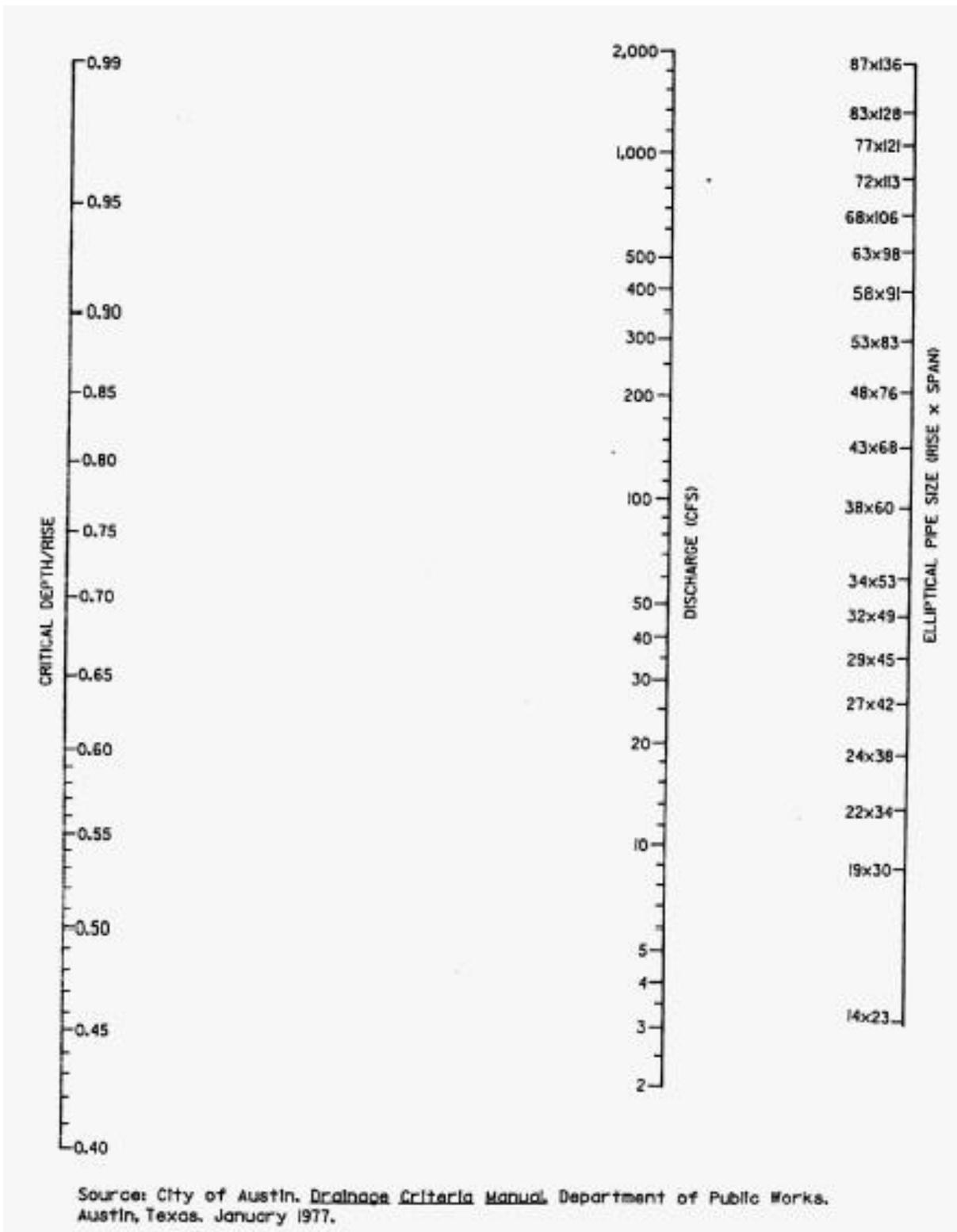
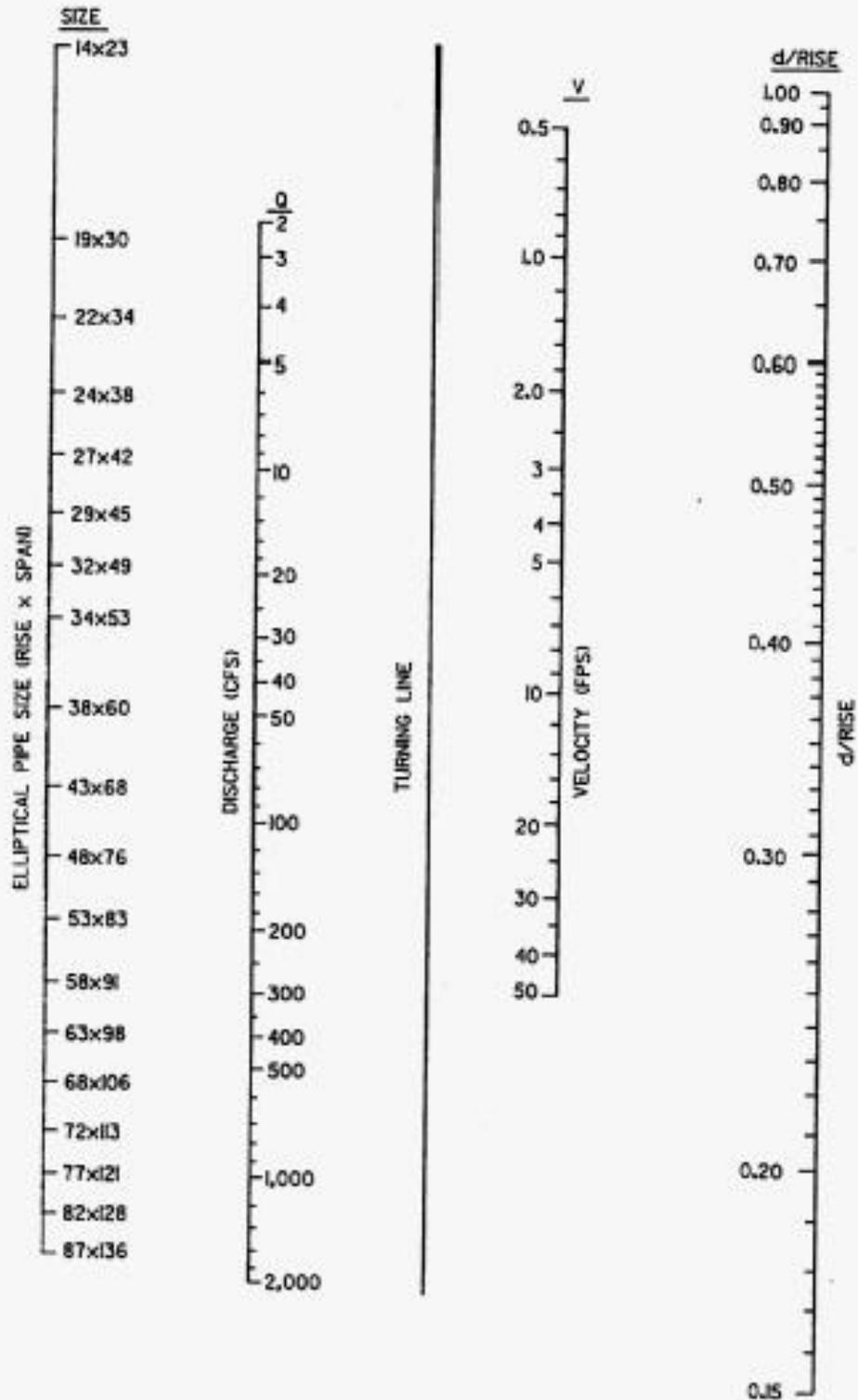


Figure 5-5: Critical Depth for Elliptical Pipe



Source: City of Austin, Drainage Criteria Manual, Department of Public Works, Austin, Texas, January 1977.

Figure 5-6: Velocity in Elliptical Pipe

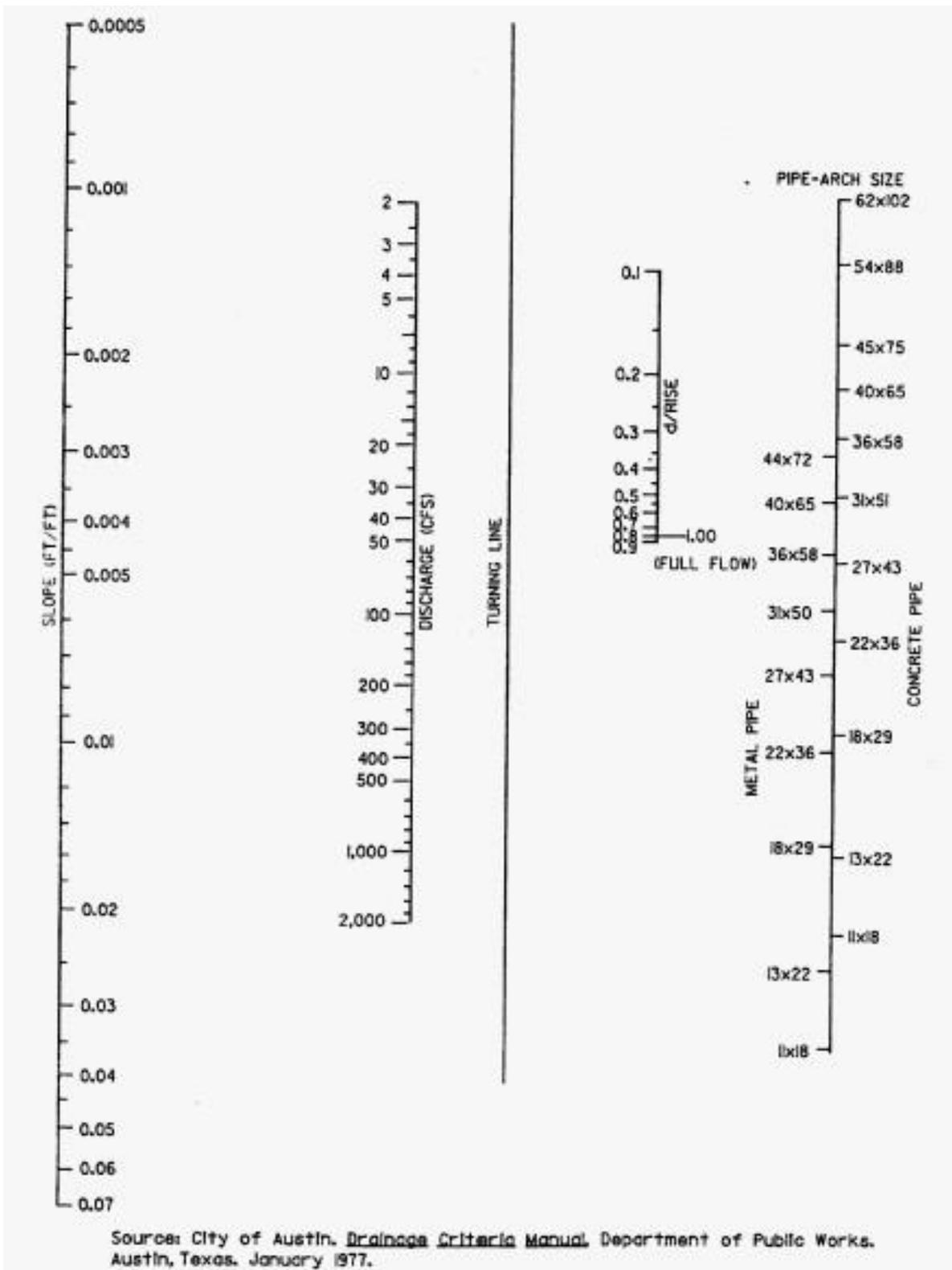


Figure 5-7: Uniform Flow for Pipe Arch

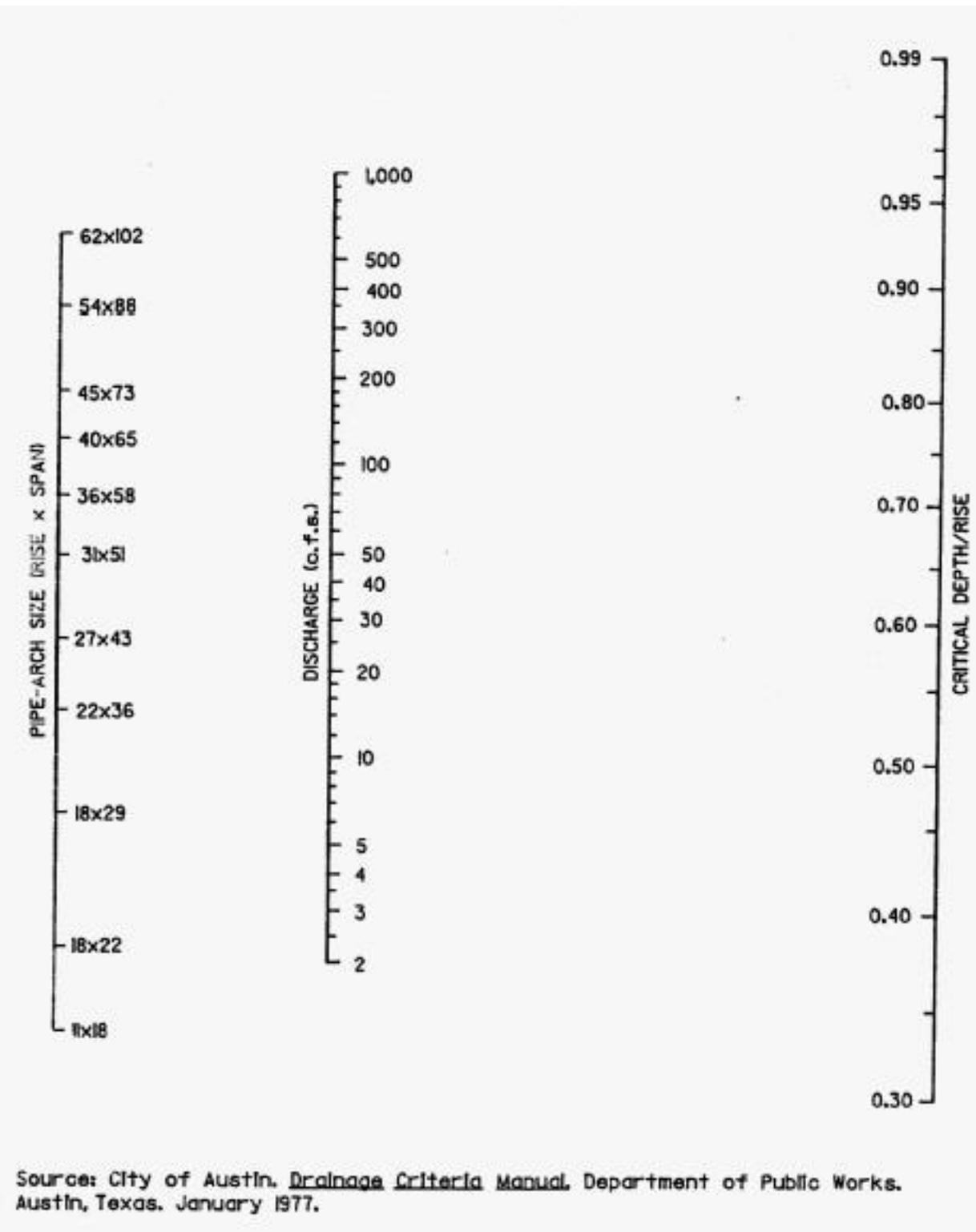


Figure 5-8: Depth of Flow for Pipe-Arch

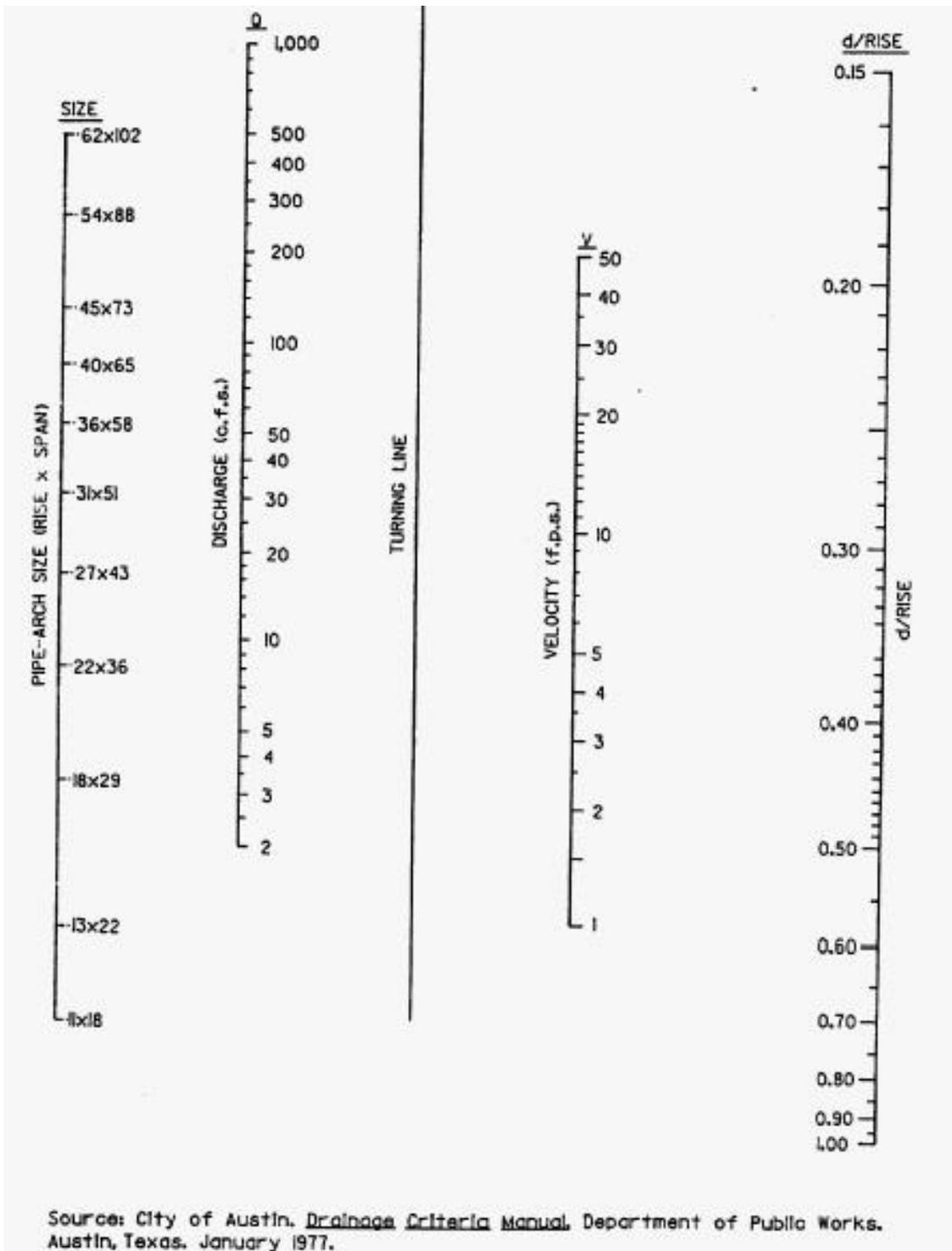


Figure 5-9: Velocity in Pipe-Arch

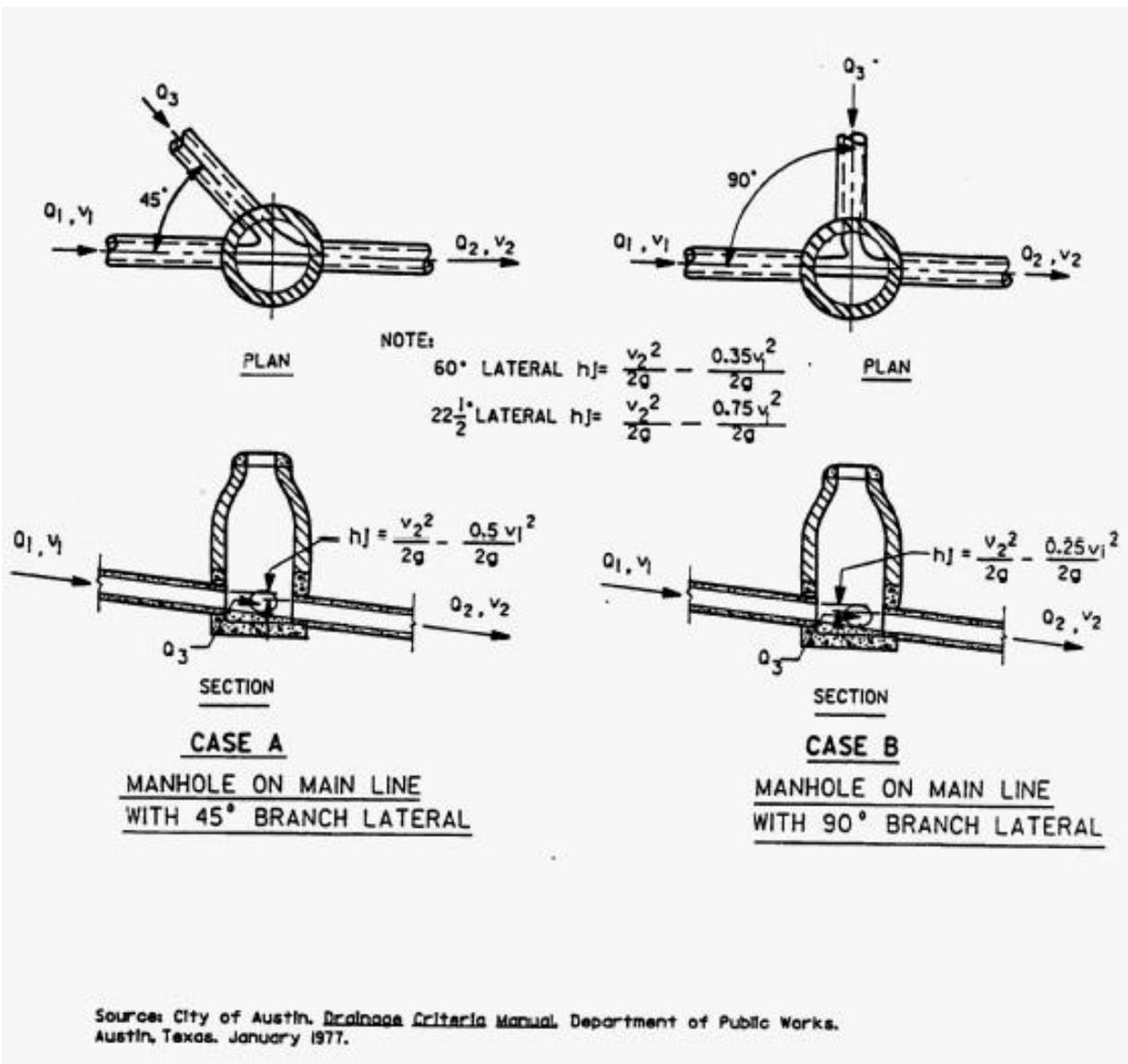


Figure 5-10: Minor Head Losses Due to Turbulence at Structures

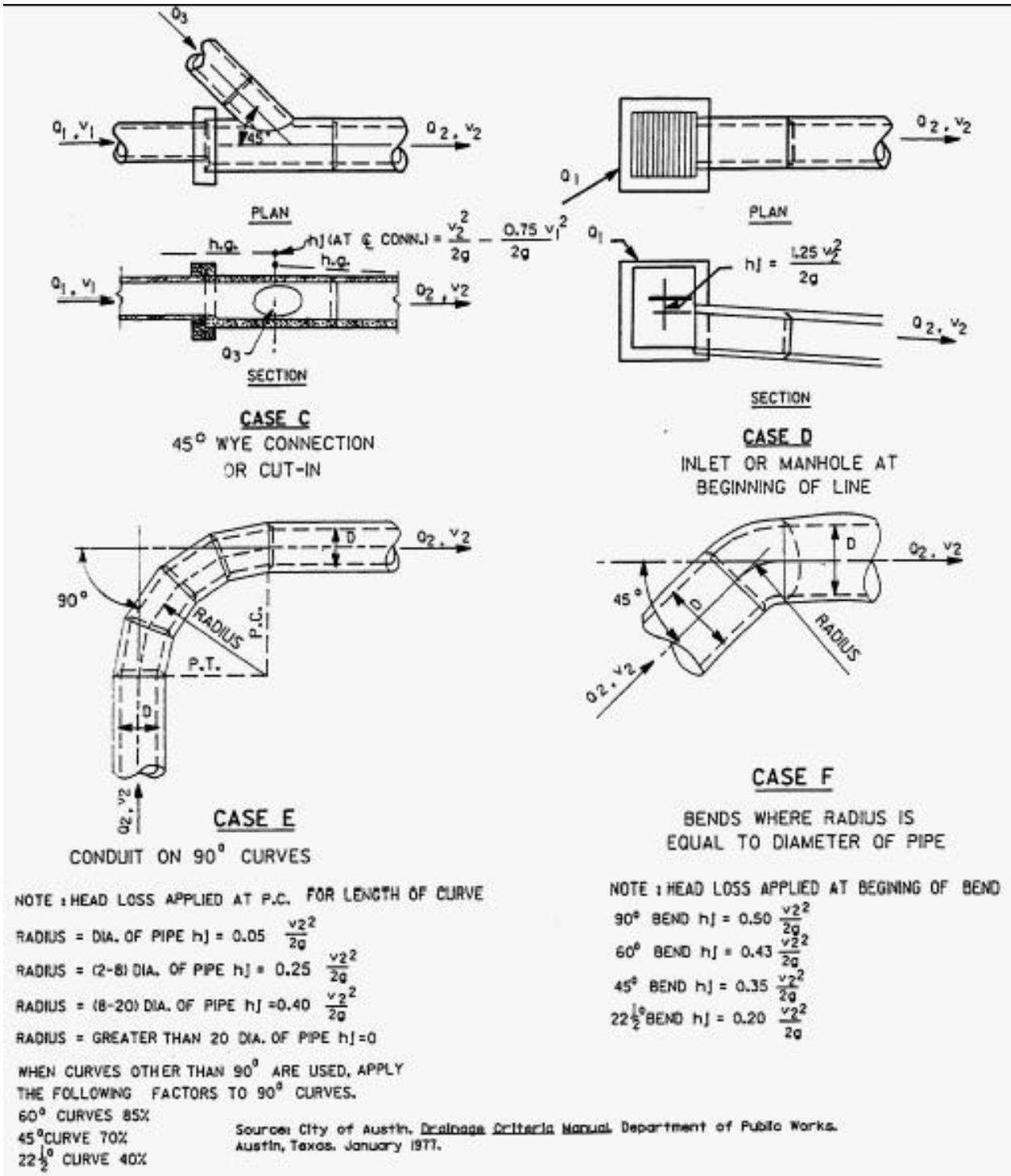


Figure 5-11: Minor Head Losses Due to Turbulence at Structures

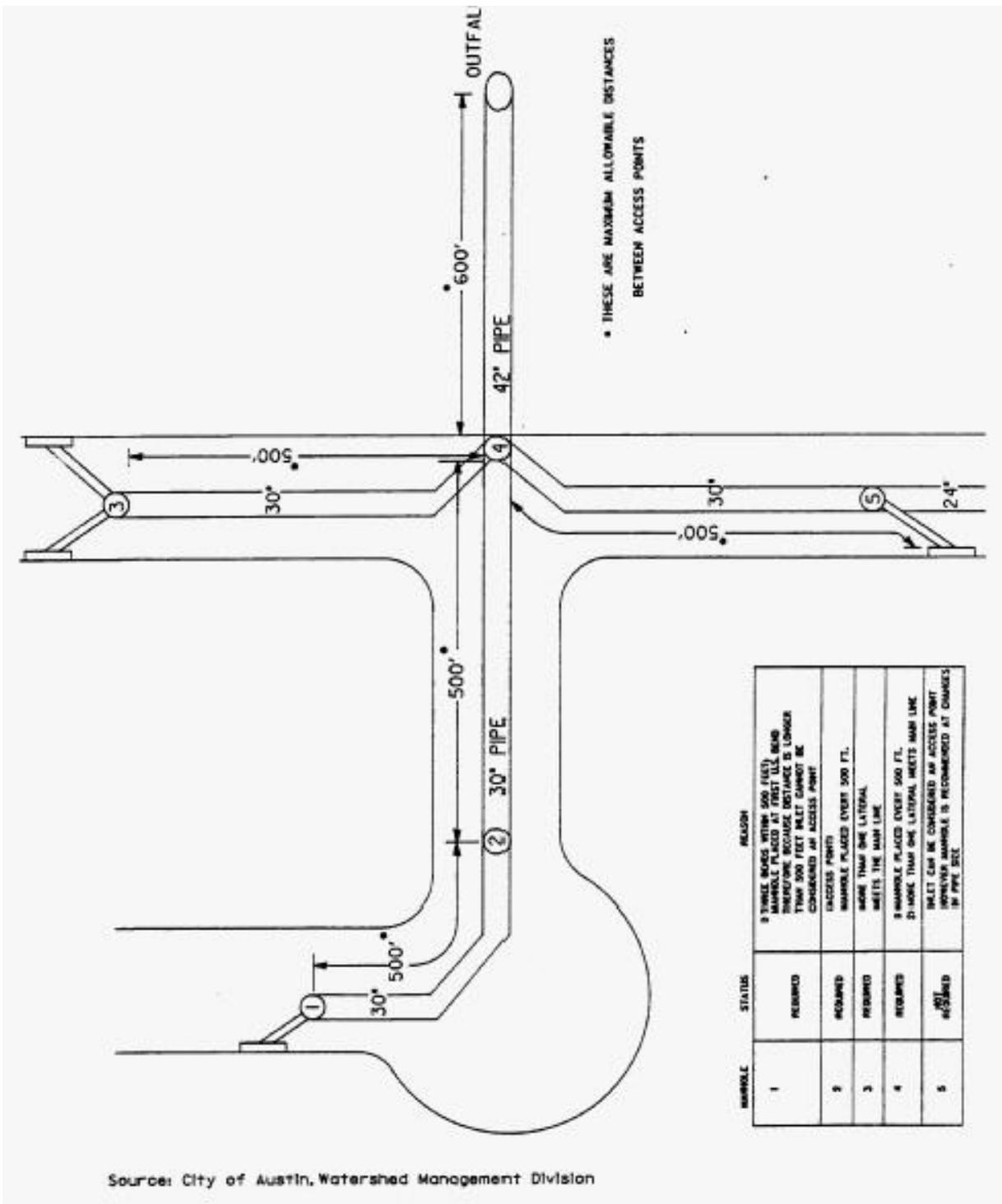


Figure 5-12: Sample Storm Sewer Layout

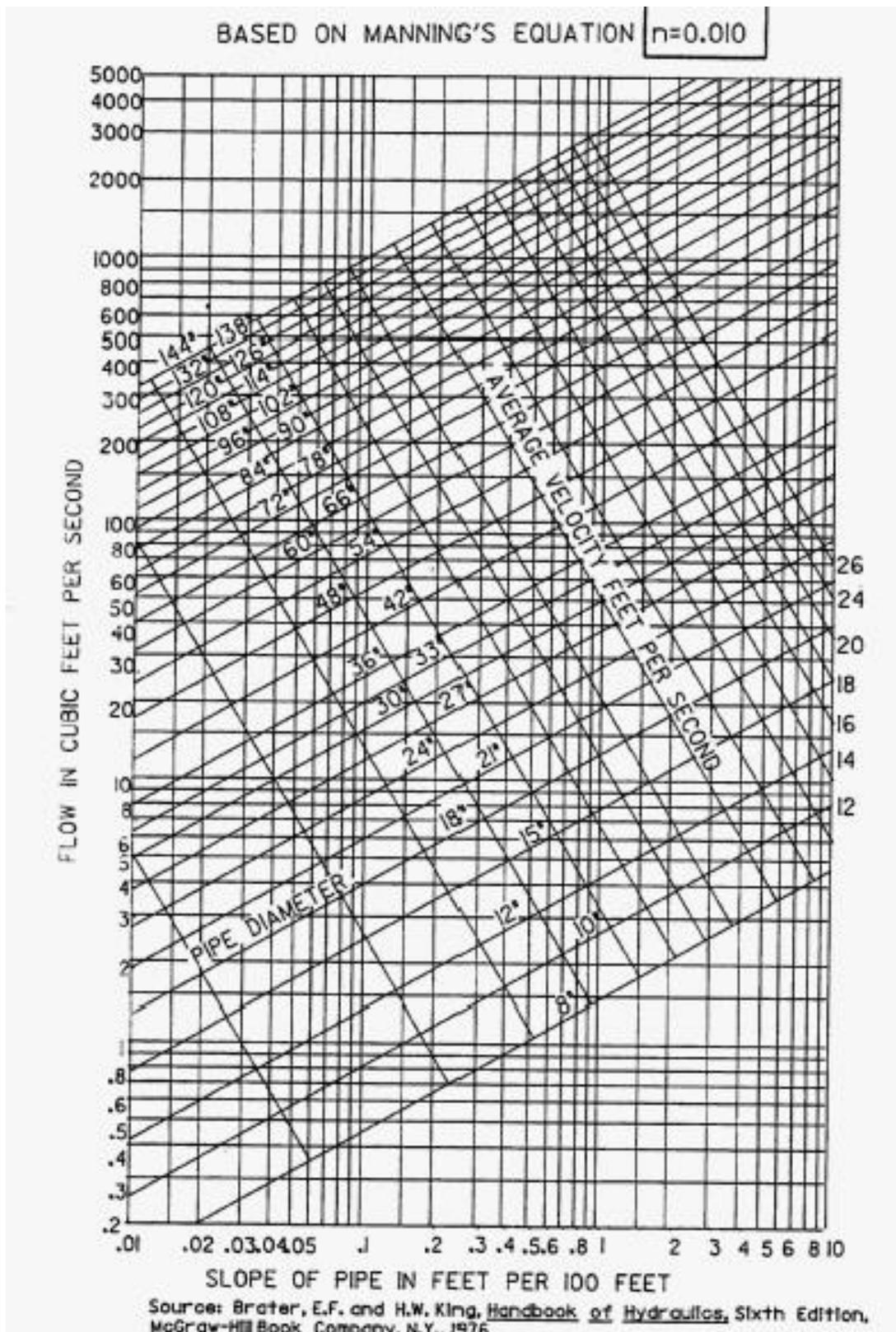


Figure 5-13: Flow for Circular Pipe Flowing Full ( $n=0.010$ )

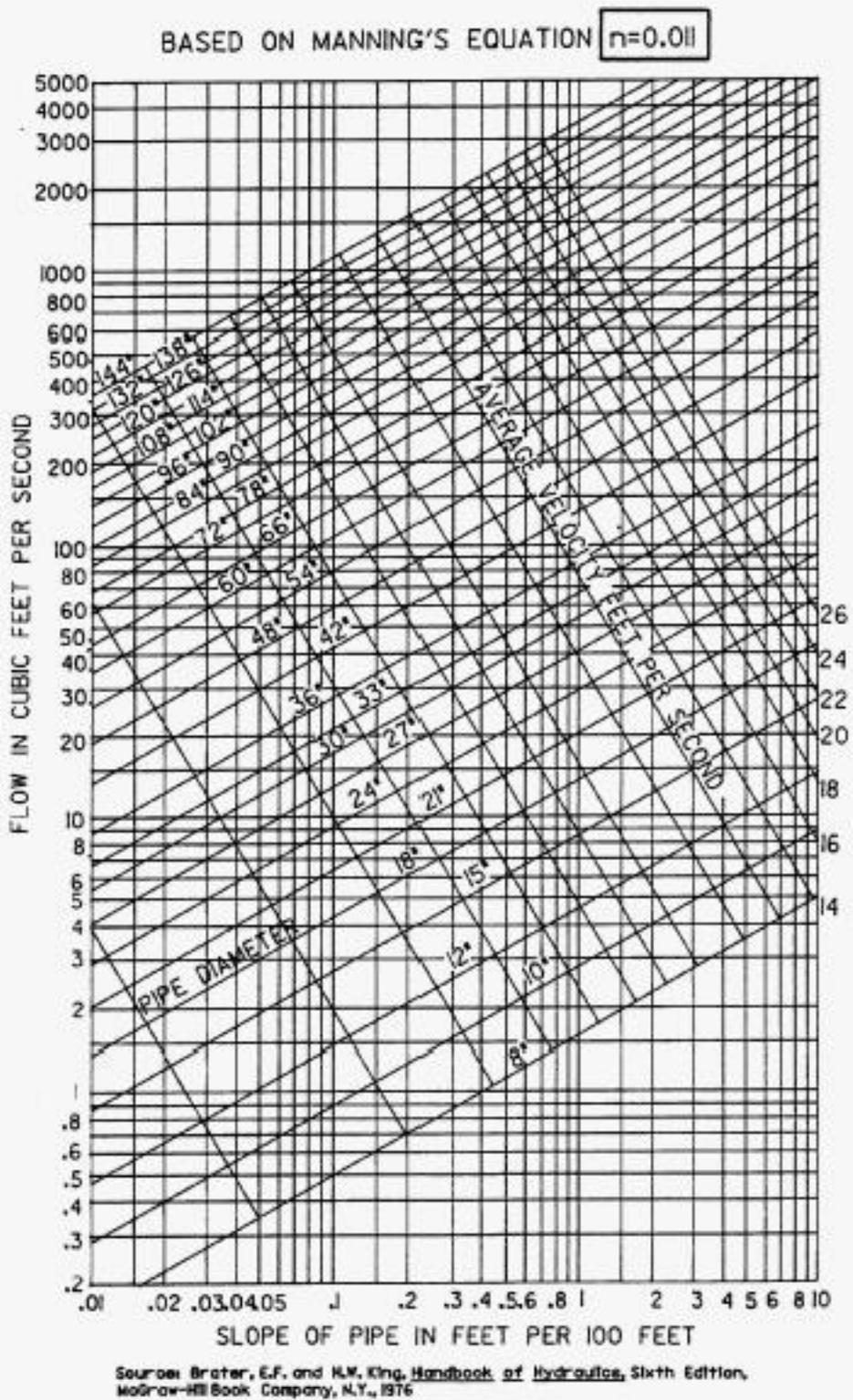


Figure 5-14: Flow for Circular Pipe Flowing Full ( $n=0.011$ )

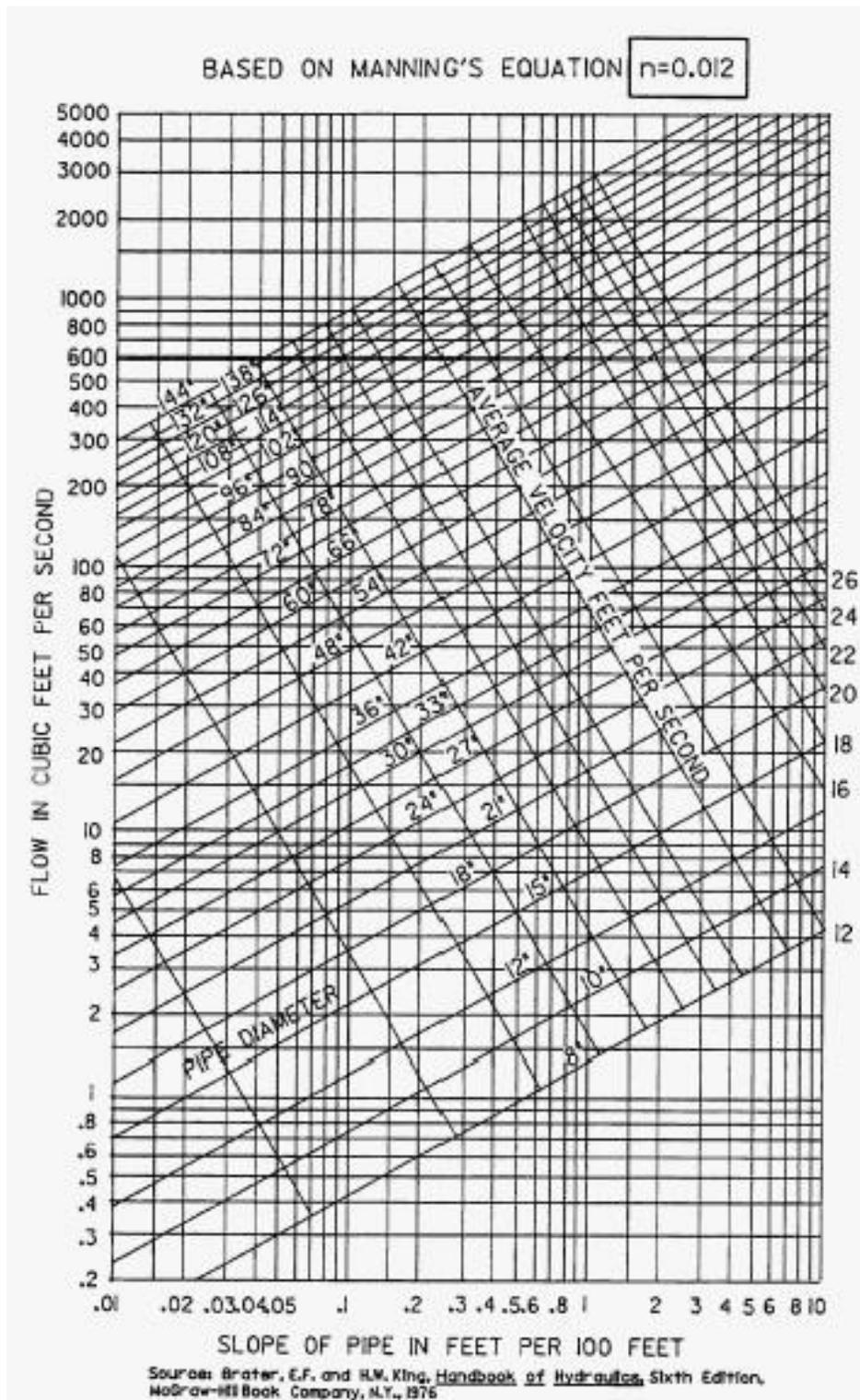
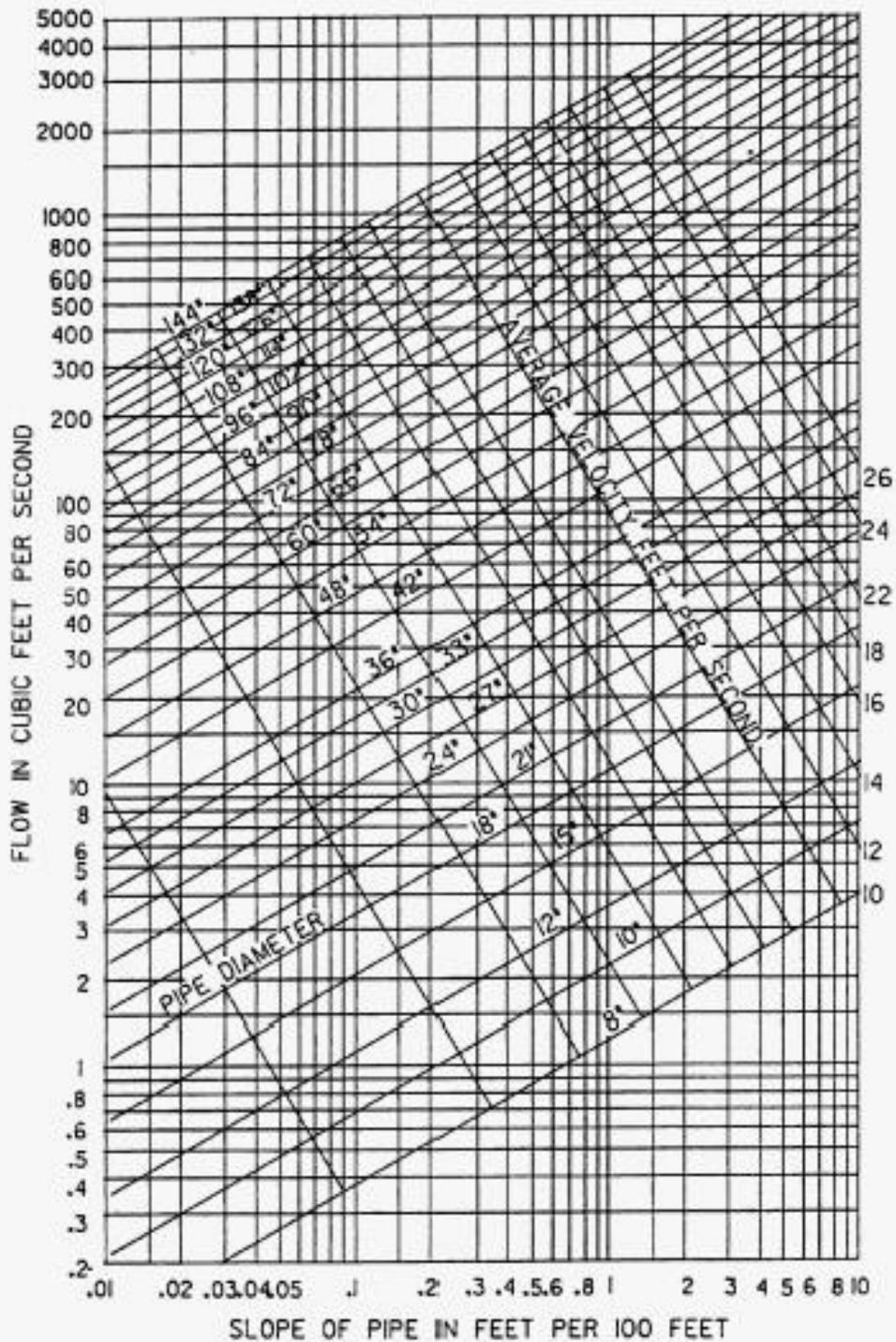


Figure 5-15: Flow for Circular Pipe Flowing Full ( $n=0.012$ )

BASED ON MANNING'S EQUATION  $n=0.013$



Source: Brater, E.F. and H.W. King, *Handbook of Hydraulics*, Sixth Edition, McGraw-Hill Book Company, N.Y., 1975

Figure 5-16: Flow for Circular Pipe Flowing Full ( $n=0.013$ )

FIGURES FROM SECTION 6

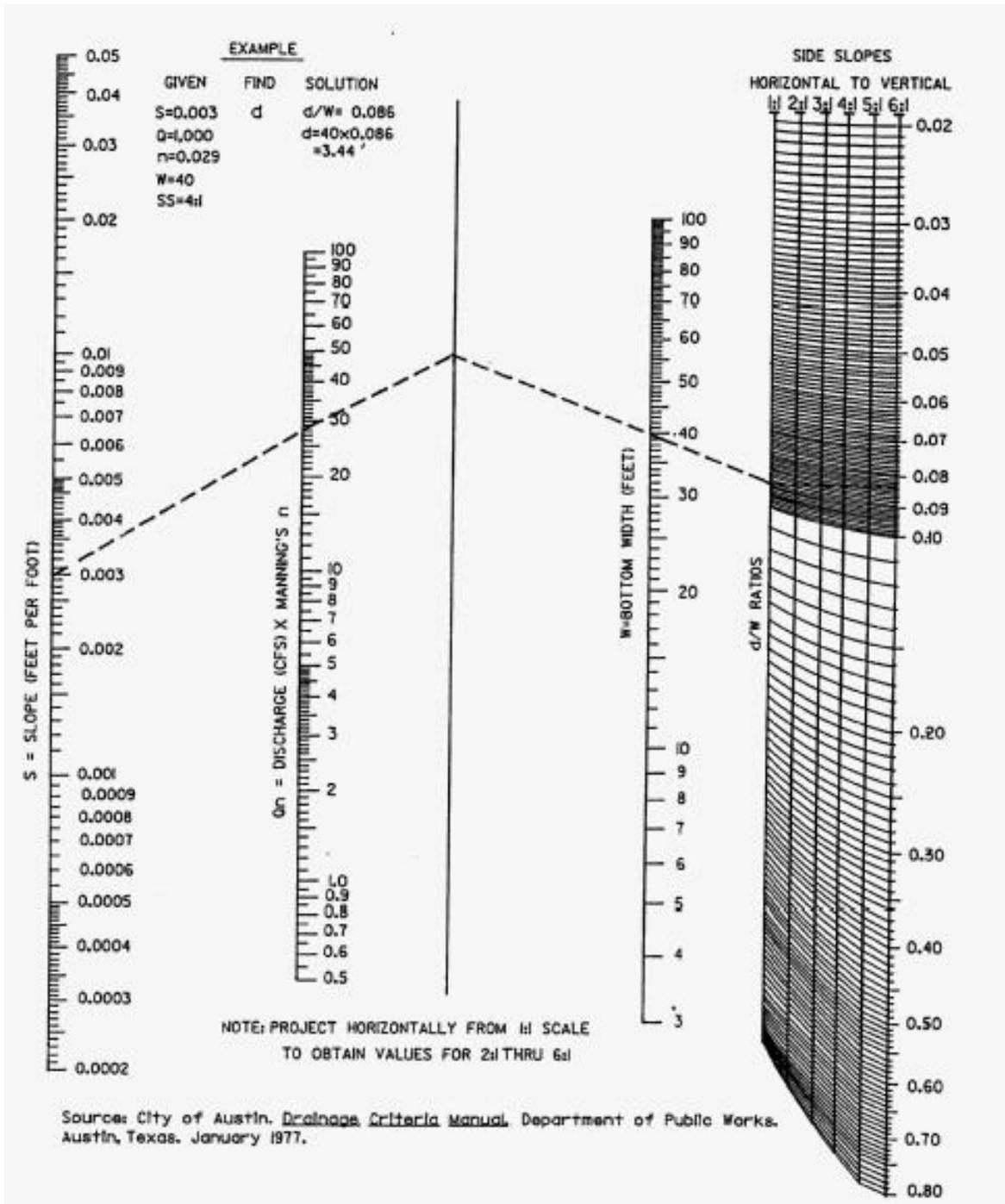


Figure 6-1: Uniform Flow for Trapezoidal Channels

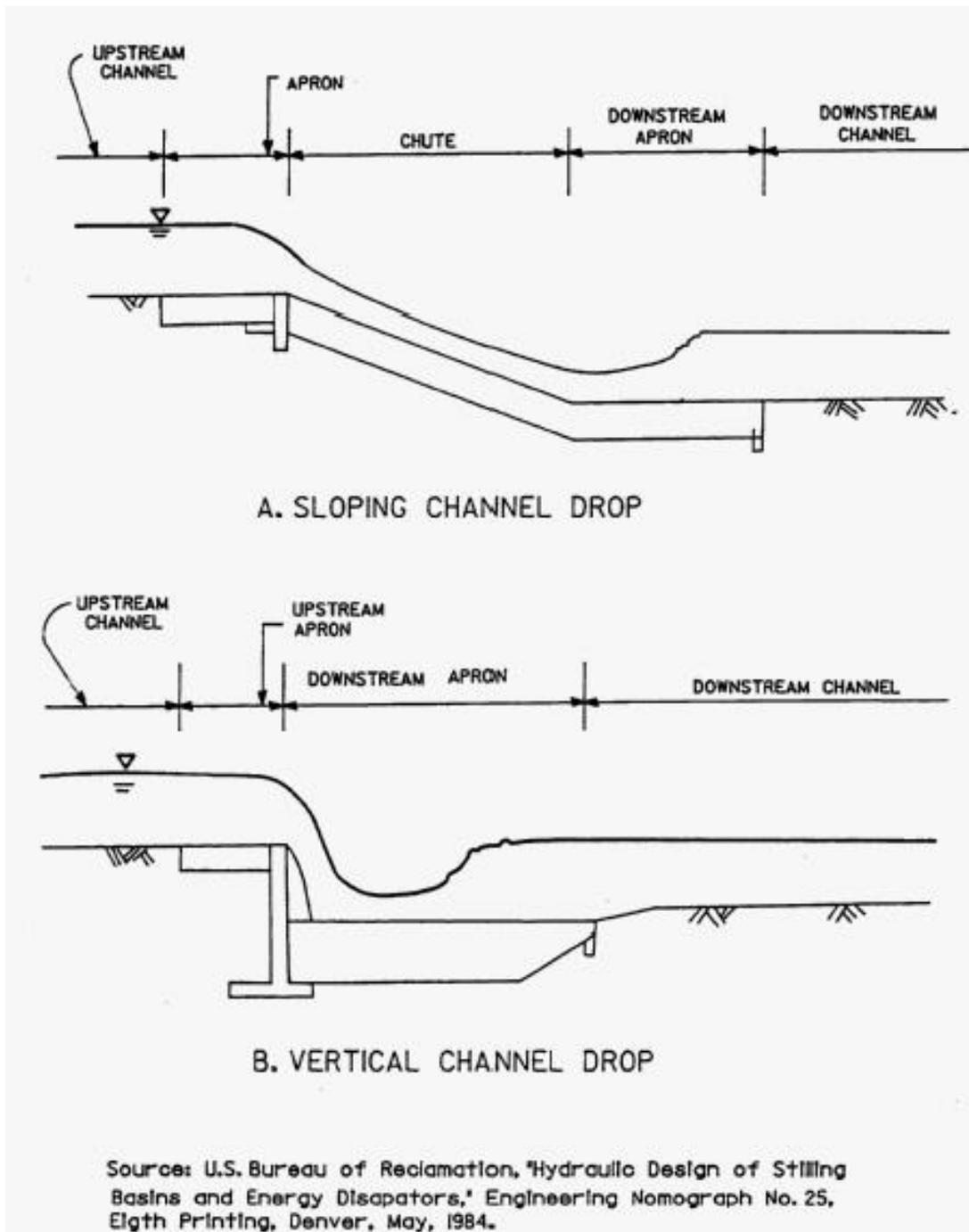
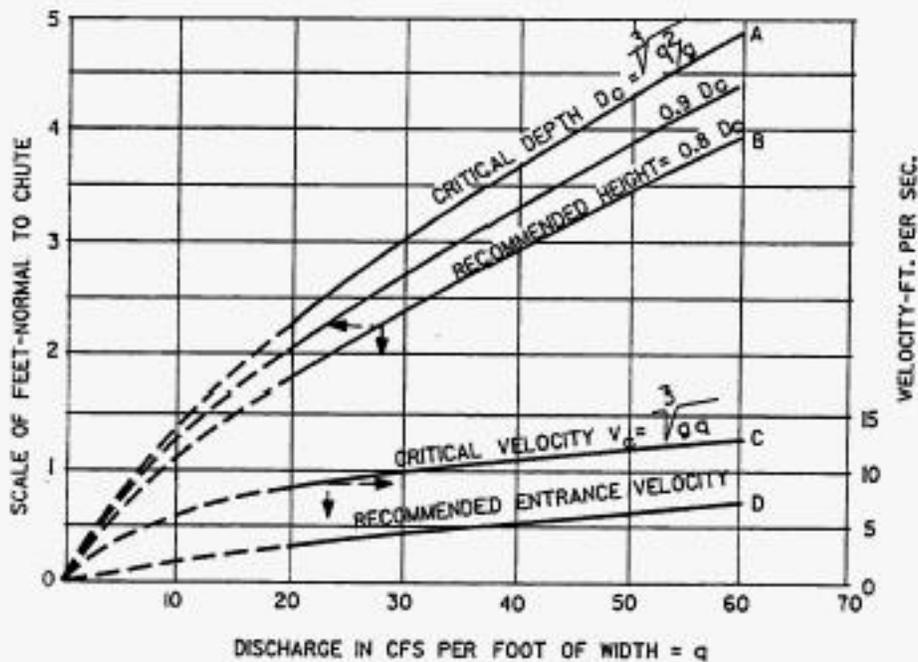
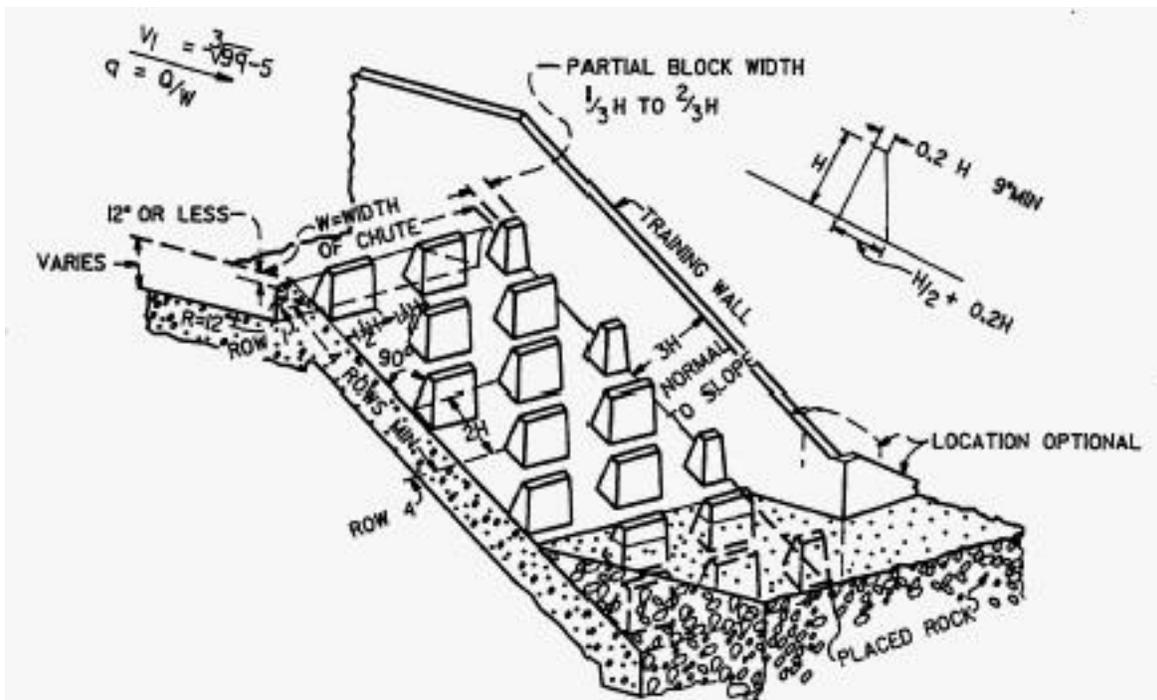


Figure 6-2: Sloping and Vertical Channel Drops



Source: U.S. Bureau of Reclamation, 'Hydraulic Design of Stilling Basins and Energy Dissipators,' Engineering Nomograph No. 25, Eighth Printing, Denver, May, 1984.

Figure 6-3: Baffled Apron and its Design Curve

Source: City of Austin, Department of Environmental Protection

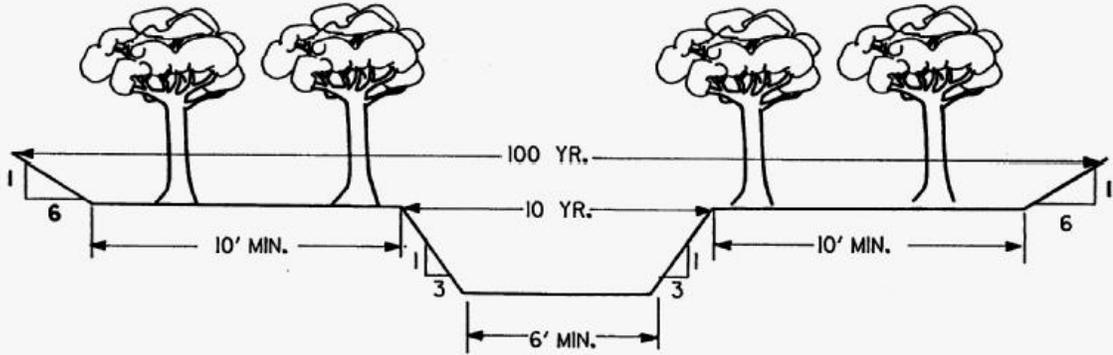


Figure 6-4: Conceptual Design of Alternative Channel

FIGURES FROM SECTION 7

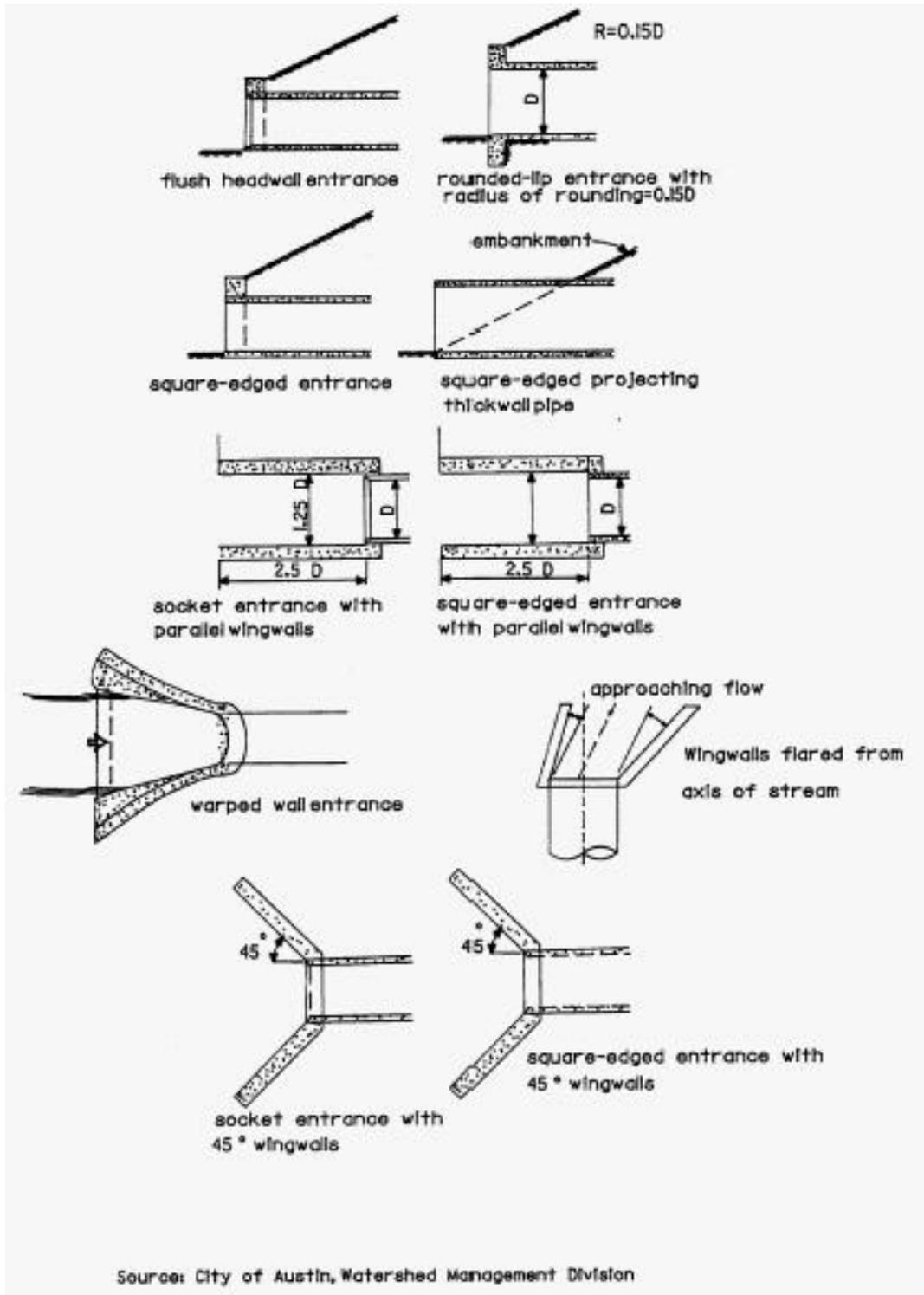


Figure 7-1: Headwall Entrance Type

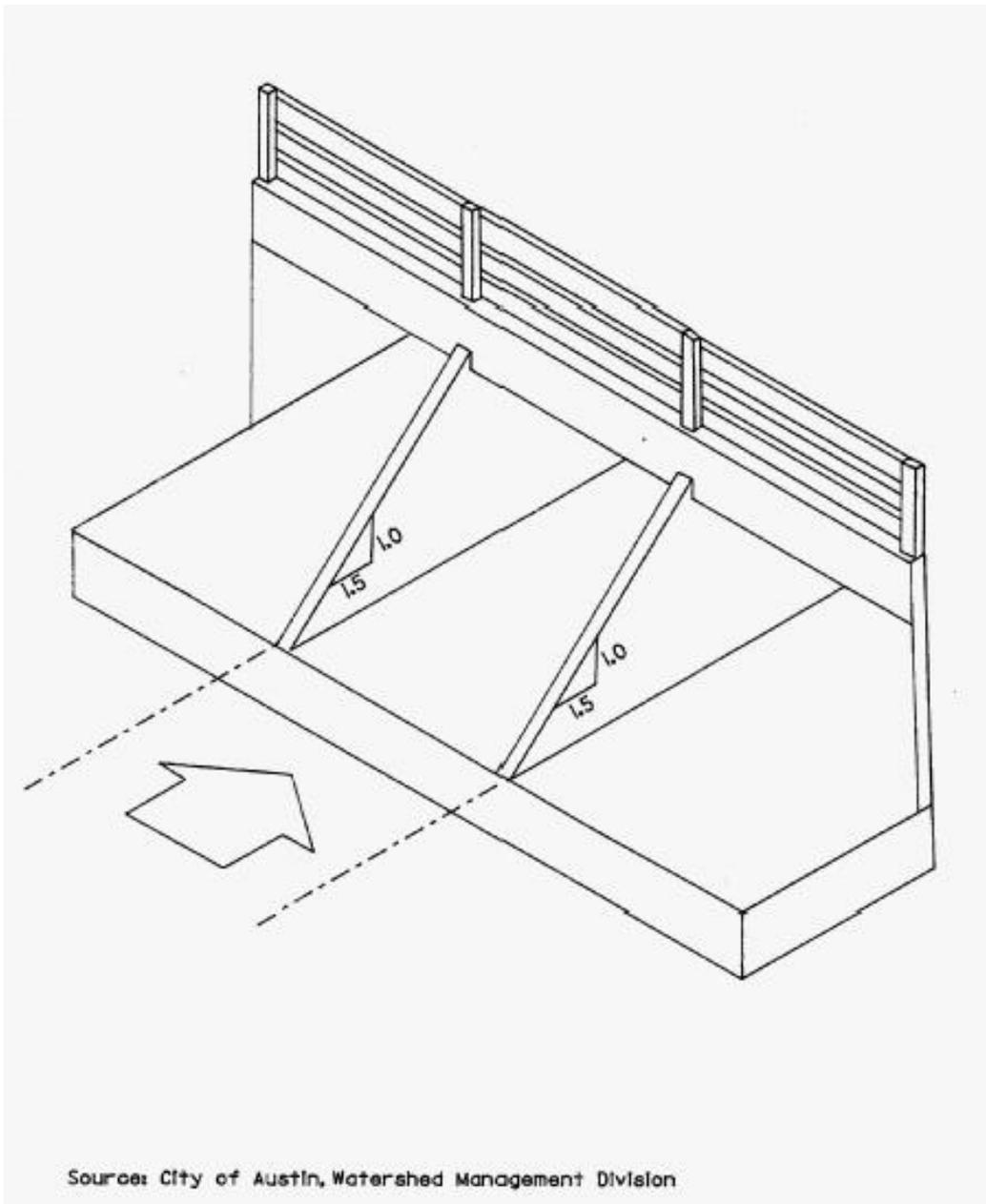
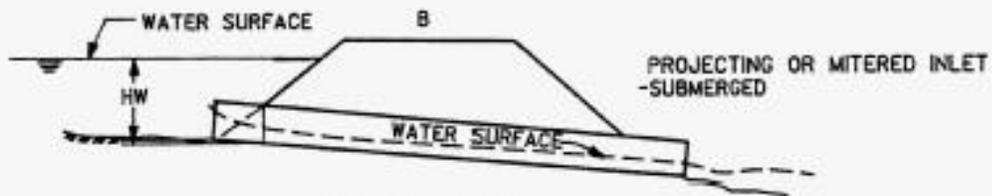
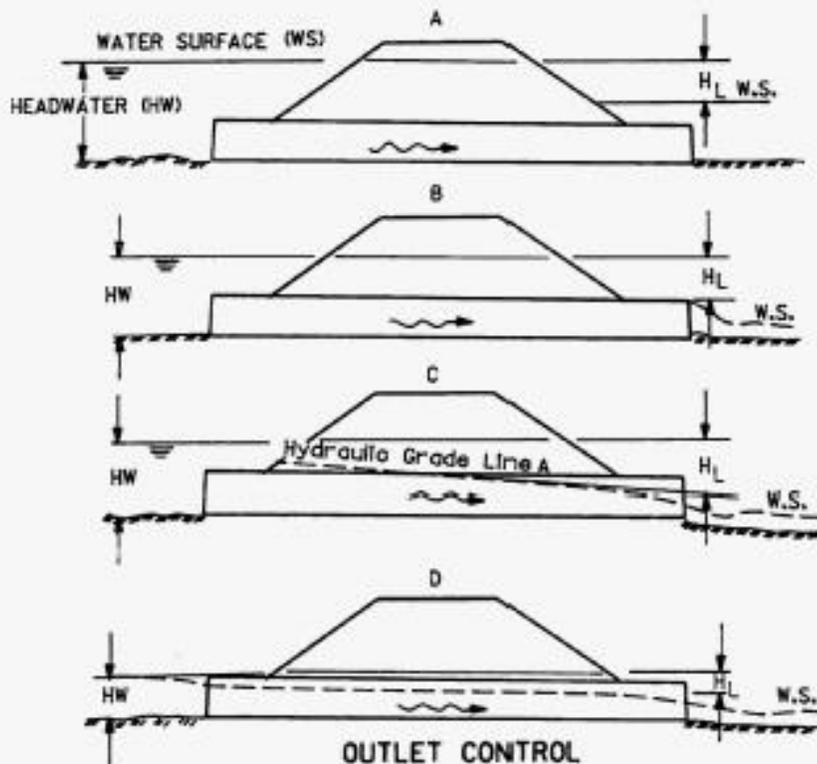


Figure 7-2: Conceptual Design of Debris Fins



### INLET CONTROL

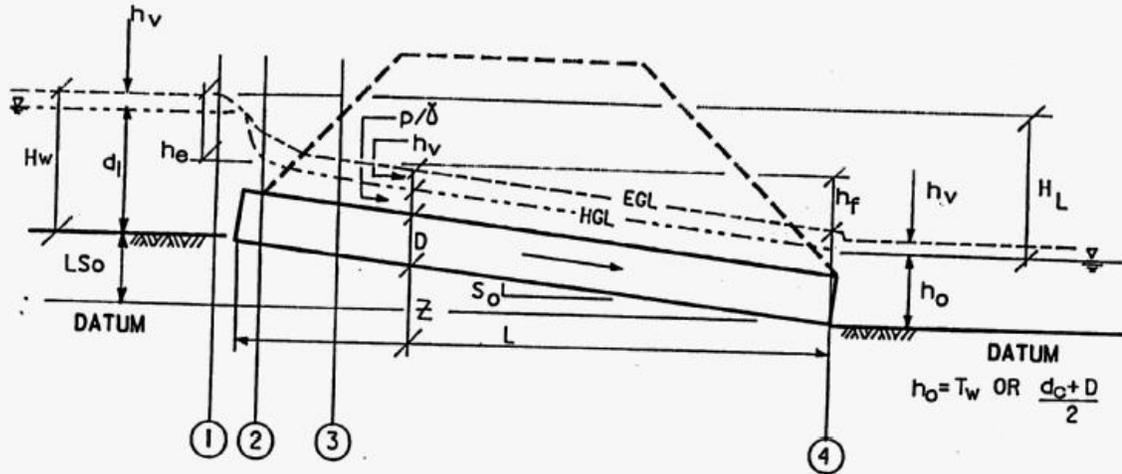
INLET CONTROL IS ONE OF THE TWO MAJOR TYPES OF CULVERT FLOW. CONDITION A WITH AN UNSUBMERGED CULVERT INLET IS PREFERRED TO THE SUBMERGED END. SLOPE, ROUGHNESS AND LENGTH OF CULVERT BARREL ARE NOT A CONSIDERATION.



### OUTLET CONTROL

OUTLET CONTROL INVOLVES THESE FACTORS: CROSS-SECTIONAL AREA OF BARREL, INLET 'GEOMETRY', PONDING, SLOPE, ROUGHNESS, TAILWATER, AND LENGTH OF CULVERT BARREL.  
 Source: Boulder County, Storm Drainage Criteria Manual

Figure 7-3: Inlet and Outlet Conditions for Culverts



**DEFINITION OF TERMS:**

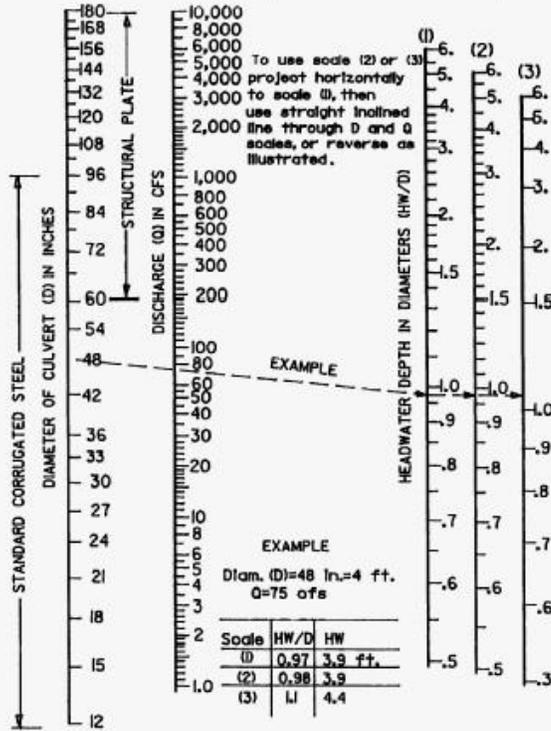
- |                                  |                                  |
|----------------------------------|----------------------------------|
| L = CULVERT LENGTH               | $P/\delta$ = PRESSURE HEAD       |
| $S_o$ = CULVERT SLOPE            | HGL = HYDRAULIC GRADE LINE       |
| $H_w$ = HEADWATER DEPTH          | EGL = ENERGY GRADE LINE          |
| $h_v$ = VELOCITY HEAD            | $T_w$ = TAILWATER DEPTH          |
| $h_e$ = HEADLOSS AT THE ENTRANCE | $h_f$ = FRICTION LOSS IN CULVERT |
| $z$ = DISTANCE FROM DATUM LINE   | $d_i$ = APPROACH DEPTH           |
| D = CULVERT DIAMETER OR RISE     |                                  |

Figure 7-4: Hydraulics of a Culvert Under Outlet Control Condition

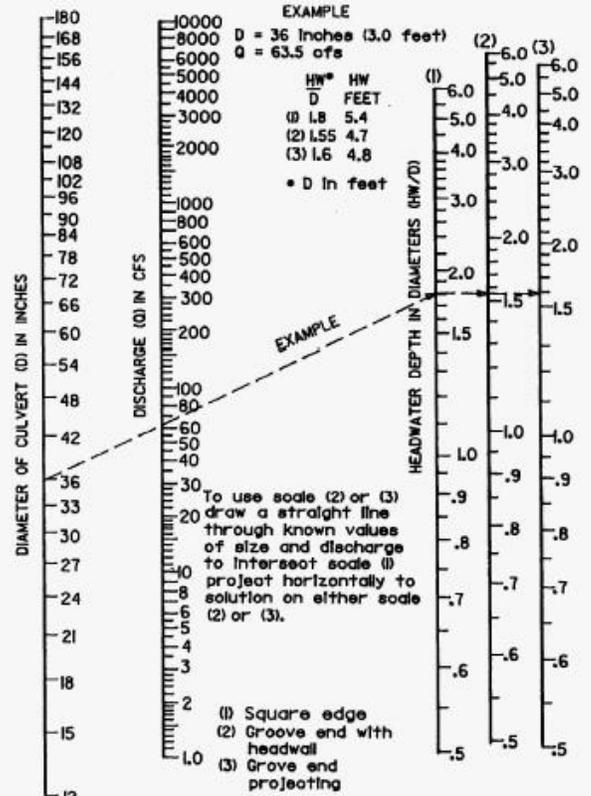
LOSS COEFFICIENT K  
FOR VARIOUS ENTRANCE TYPES

HW/D SCALE	ENTRANCE TYPE	COEFFICIENT
(1)	Headwall, sq. edges or end Section conforming to fill slope	0.5
(2)	Mitered to conform to slope	0.7
(3)	Projecting from fill	0.9

Sources: 'Concrete Pipe Design Manual', ACPA 1970  
'Handbook of Steel Drainage & Highway Construction Products', AISI 1971



(A) CORRUGATED STEEL PIPE



(B) REINFORCED CONCRETE PIPE

Figure 7-5: Inlet Control Nomograph, Circular Pipe

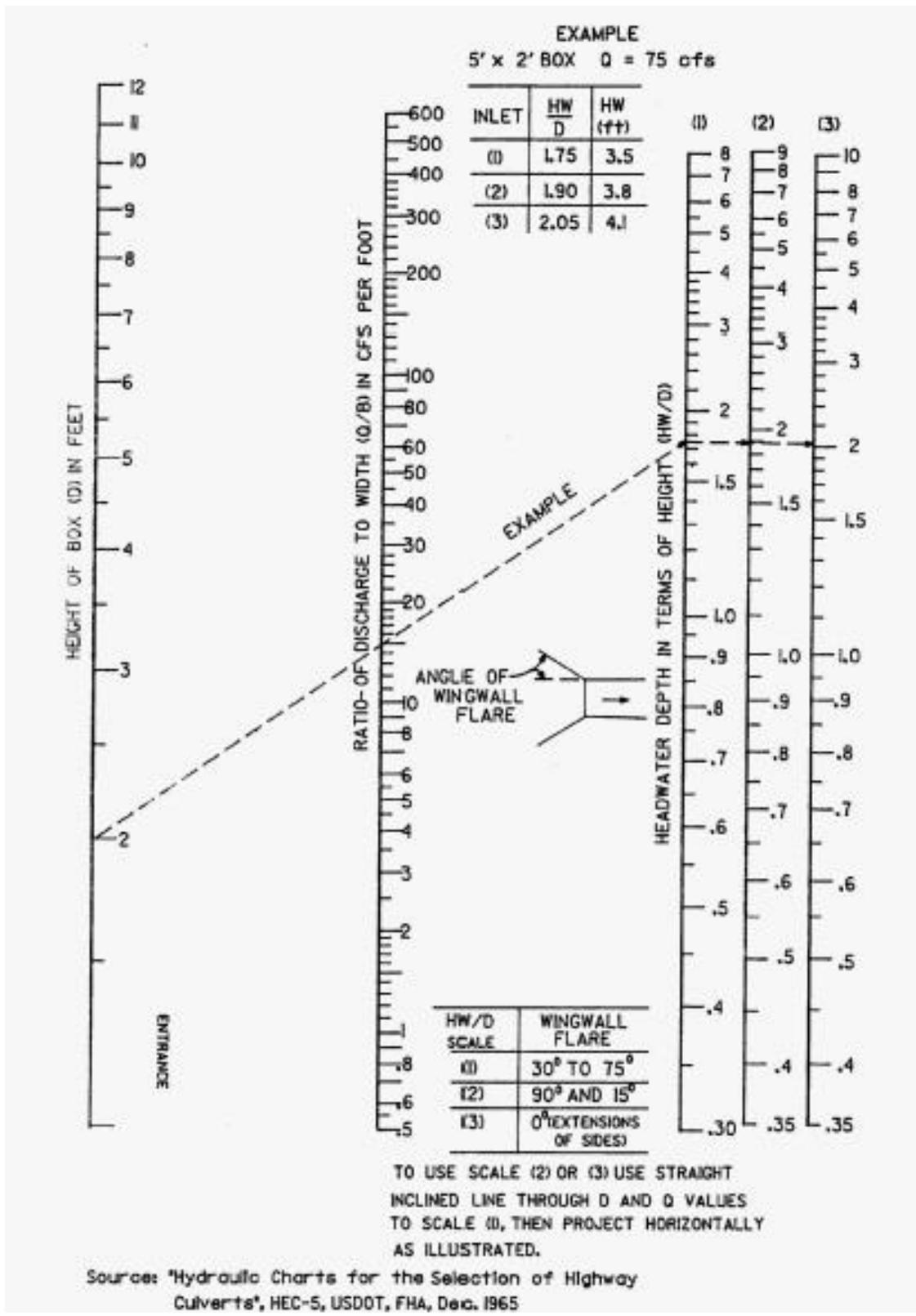


Figure 7-6: Inlet Control Nomograph, Box Culverts

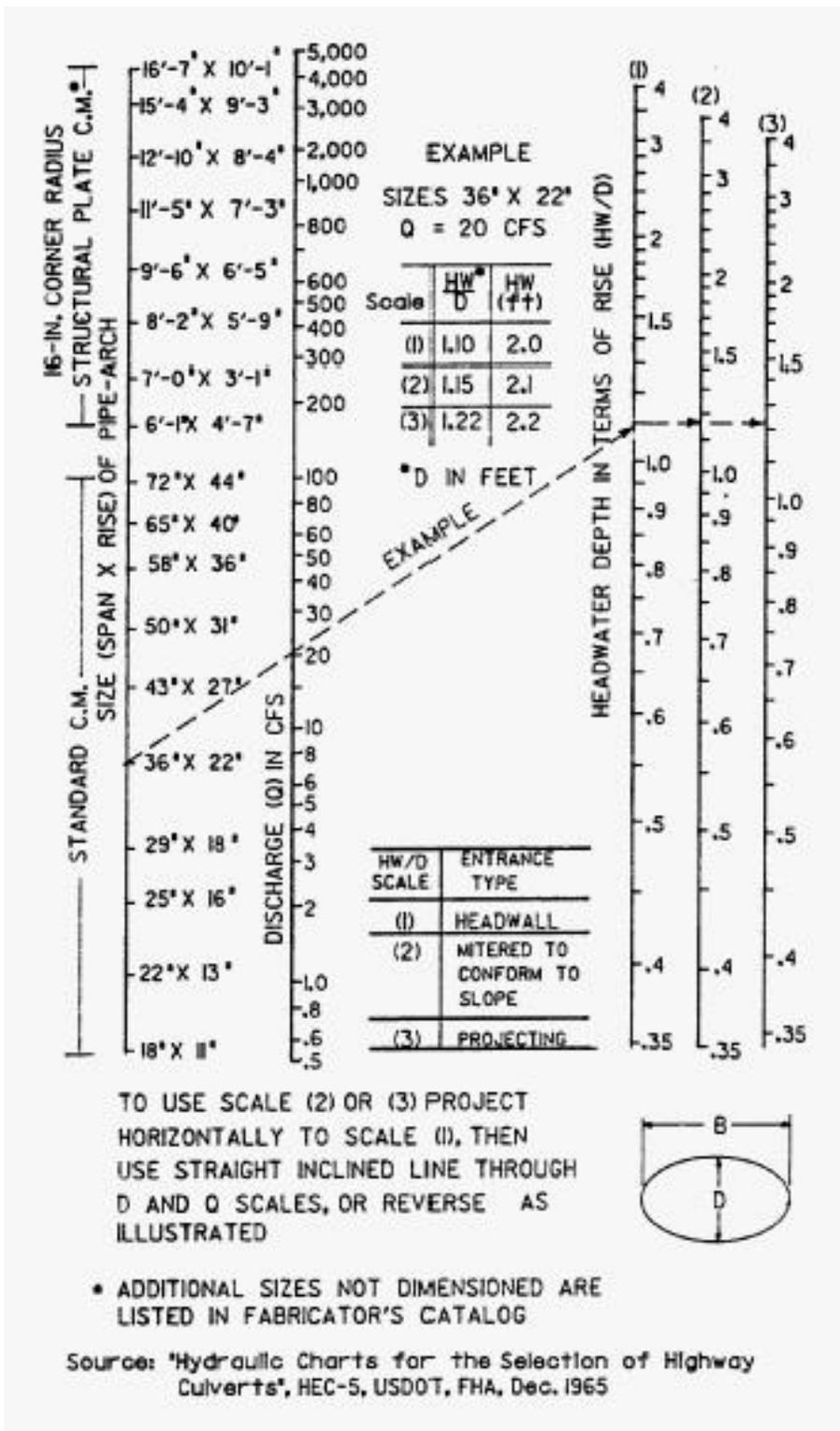
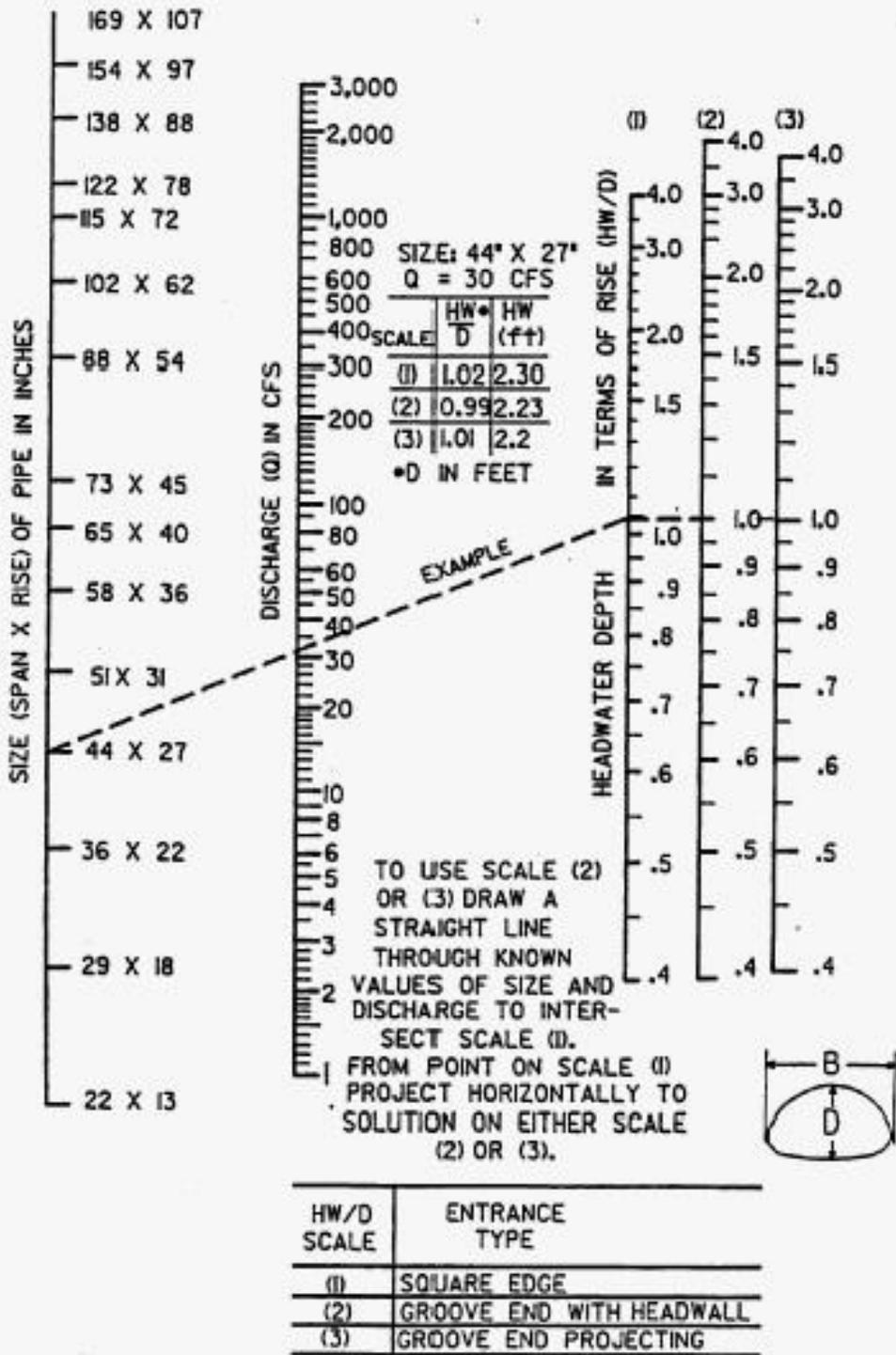
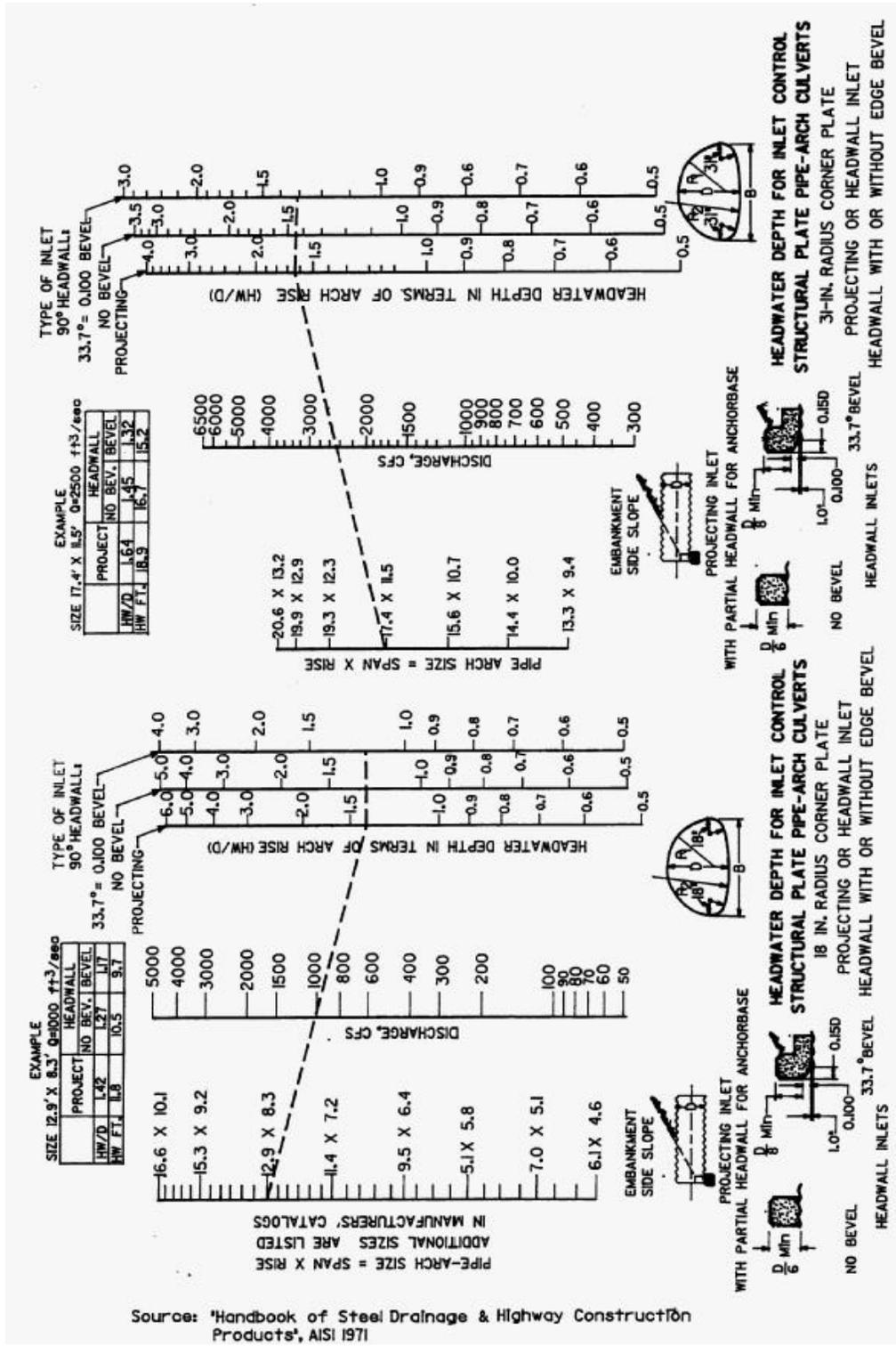


Figure 7-7: Inlet Control Nomograph, CSP Arch



Source: 'Concrete Pipe Design Manual', ACPA 1970

Figure 7-8: Inlet Control Nomograph, RCP Arch



Source: 'Handbook of Steel Drainage & Highway Construction Products', AISI 1971

Figure 7-9: Inlet Control Nomograph, SSP Arch

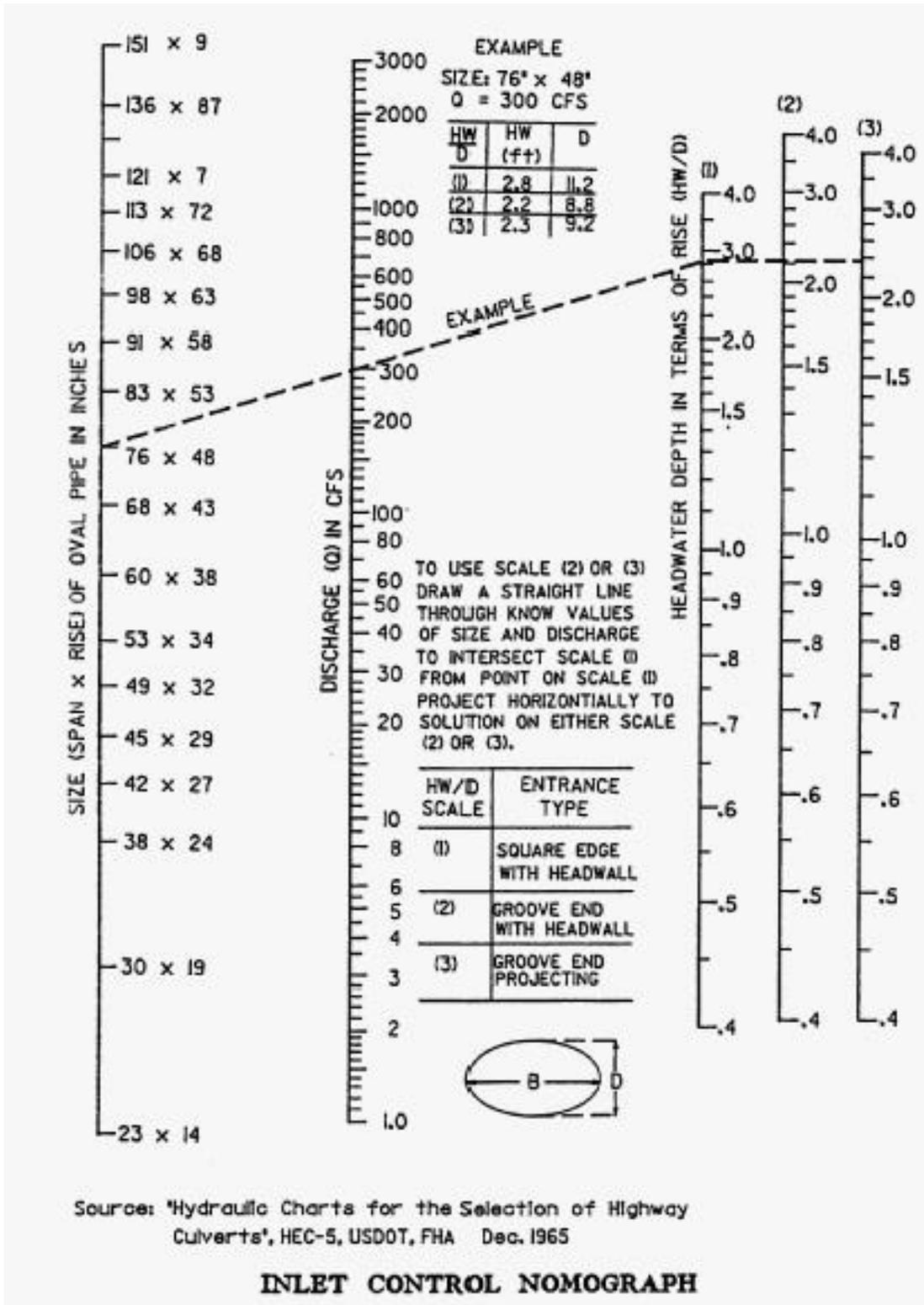
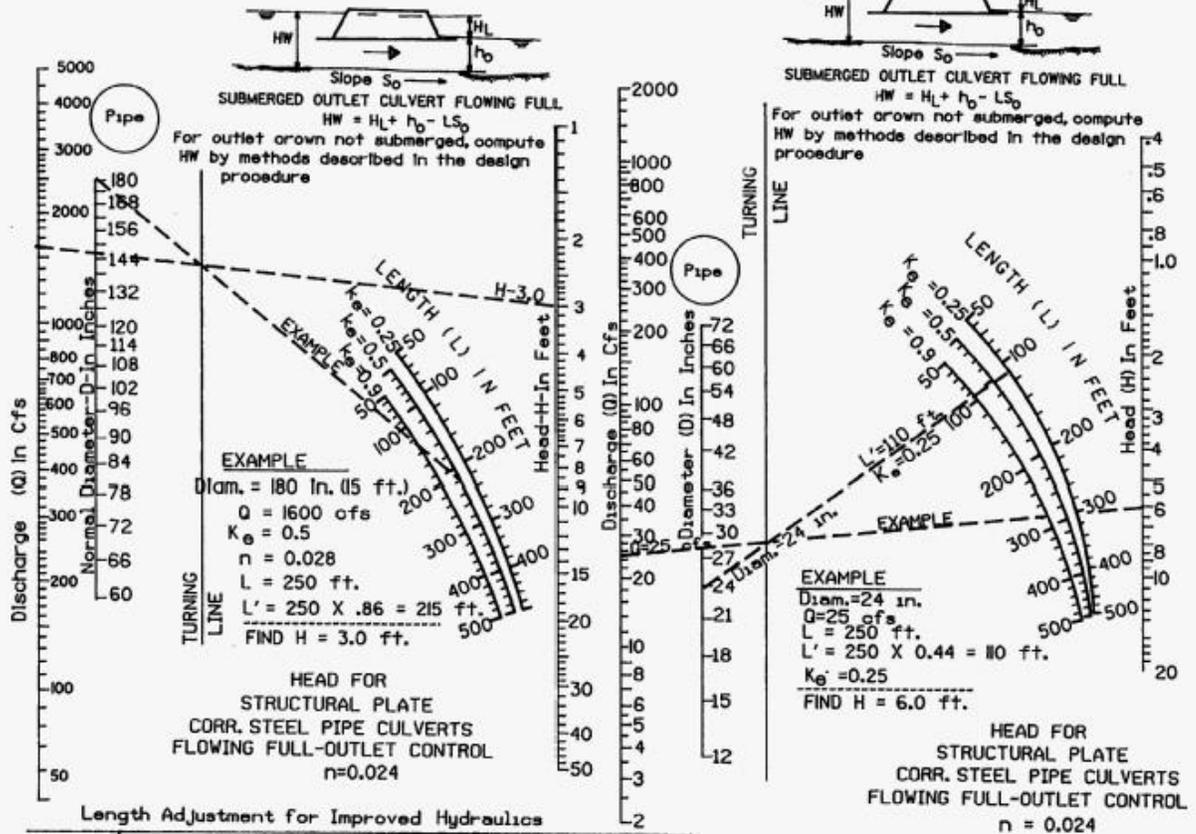


Figure 7-10: Inlet Control Nomograph, RCP Elipse

Source: Handbook of Steel Drainage & Highway Construction Products, AISI 1971



Length Adjustment for Improved Hydraulics

Pipe Diam. in Feet	Roughness Factor		Length Adjustment Factor $(\frac{n'}{n})^2$
	Curves Based on $n =$	Actual $n' = *$	
5'	.0328	.033	1.0
7'	.0320	.032	1.0
10'	.0311	.030	0.93
15'	.0302	.028	0.86

Figure 7-11: Outlet Control Nomograph, Circular CSP

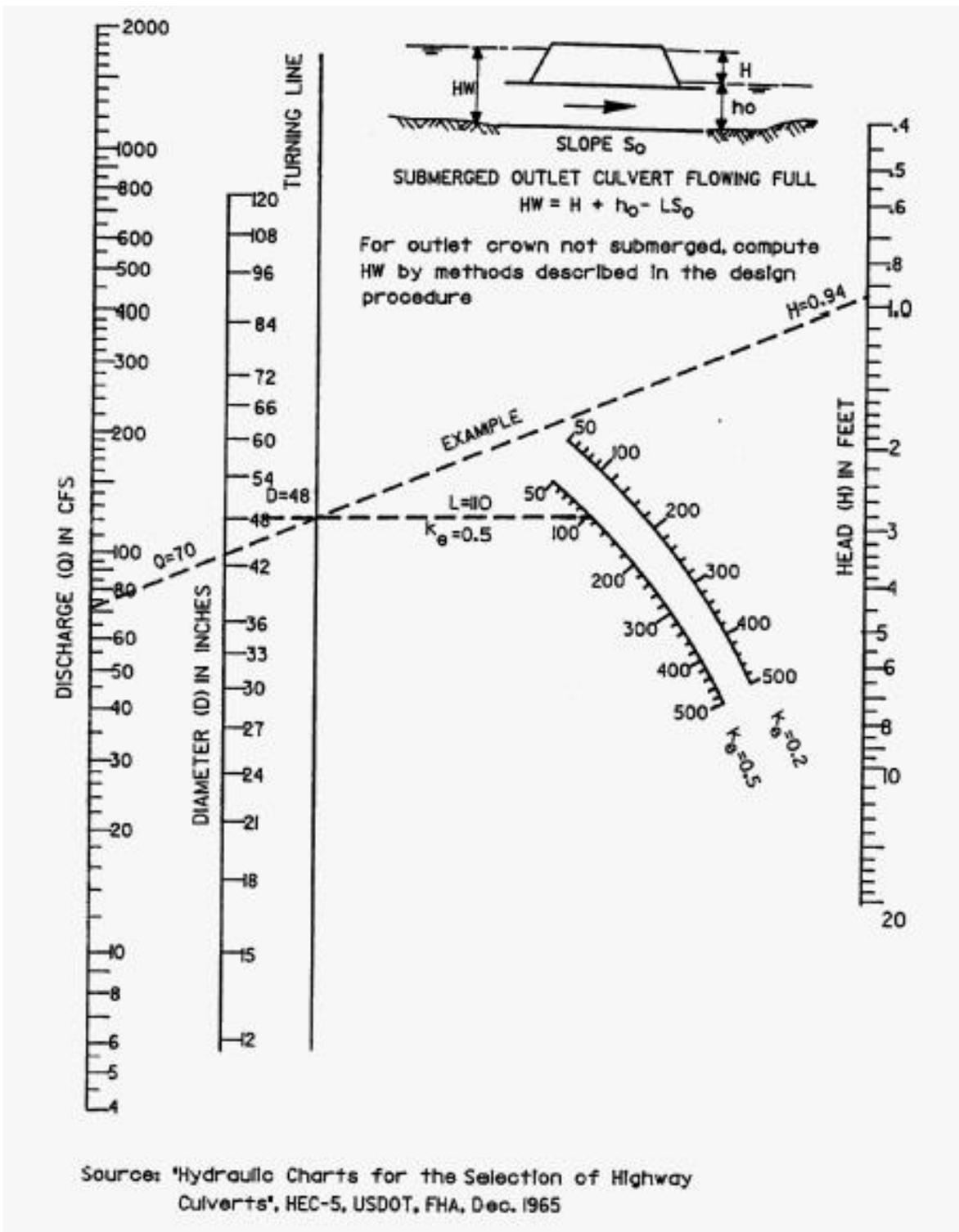


Figure 7-12: Outlet Control Nomograph, Circular RCP

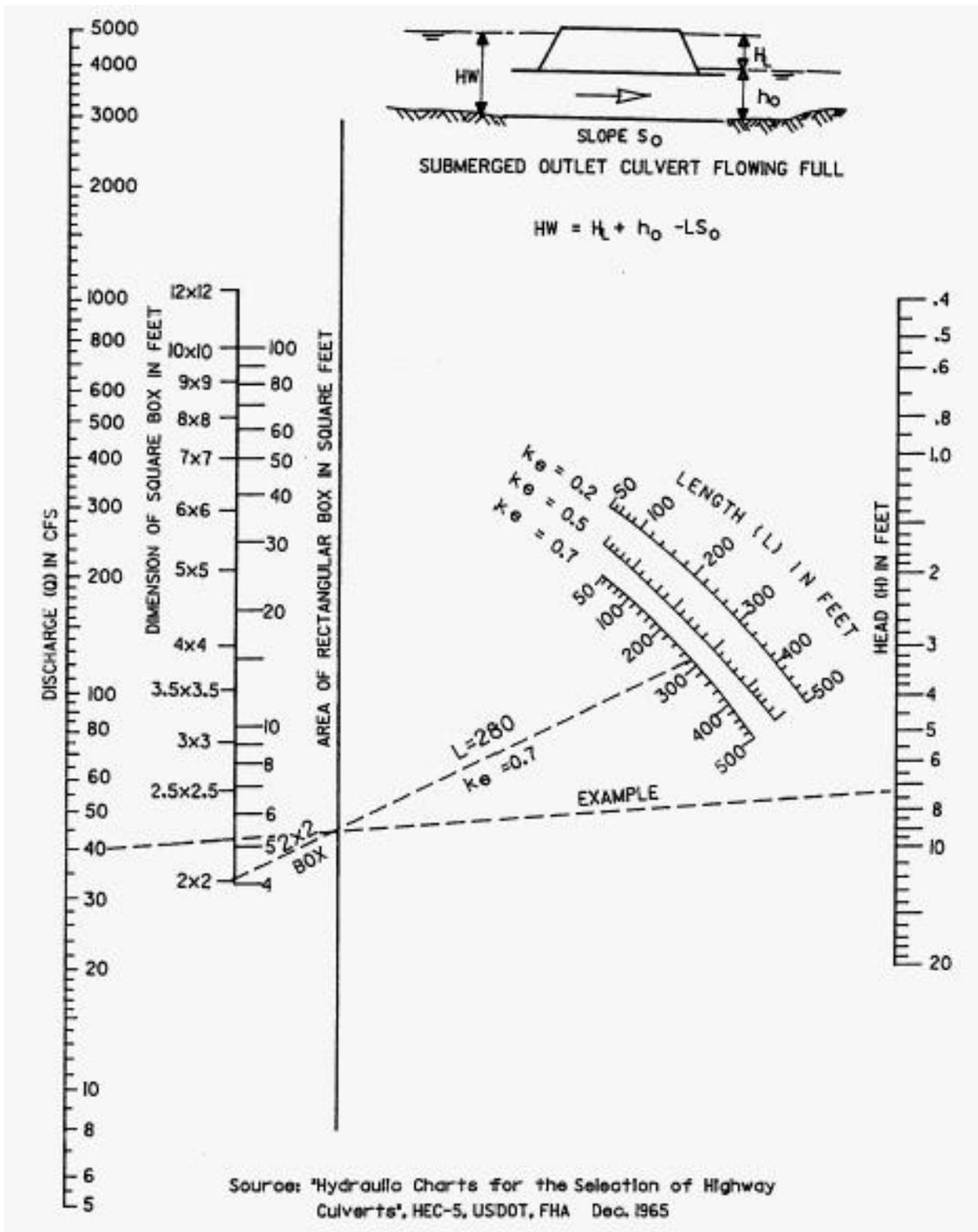


Figure 7-13: Outlet Control Nomograph, Box Culverts

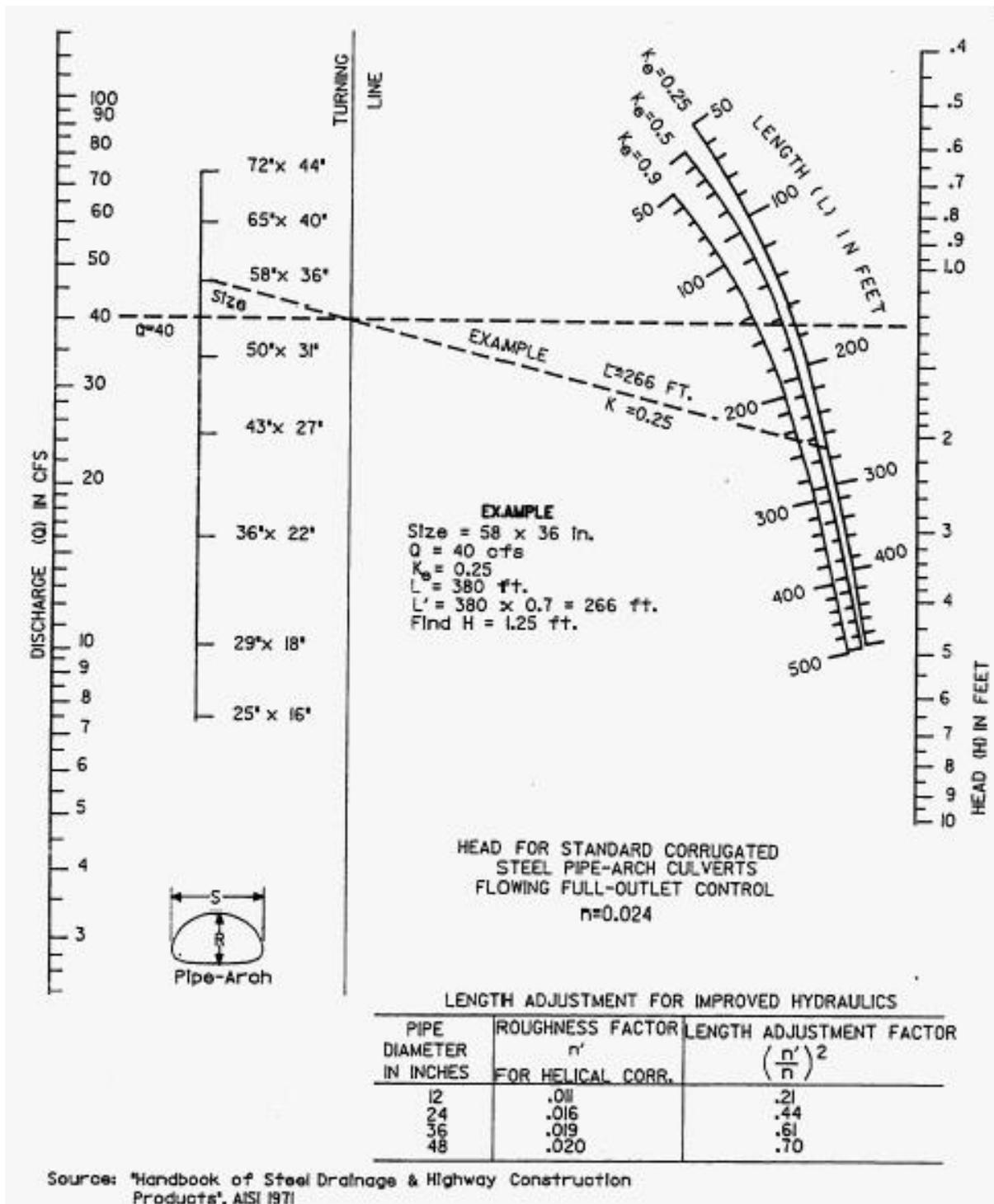


Figure 7-14: Outlet Control Nomograph, CSP Arch

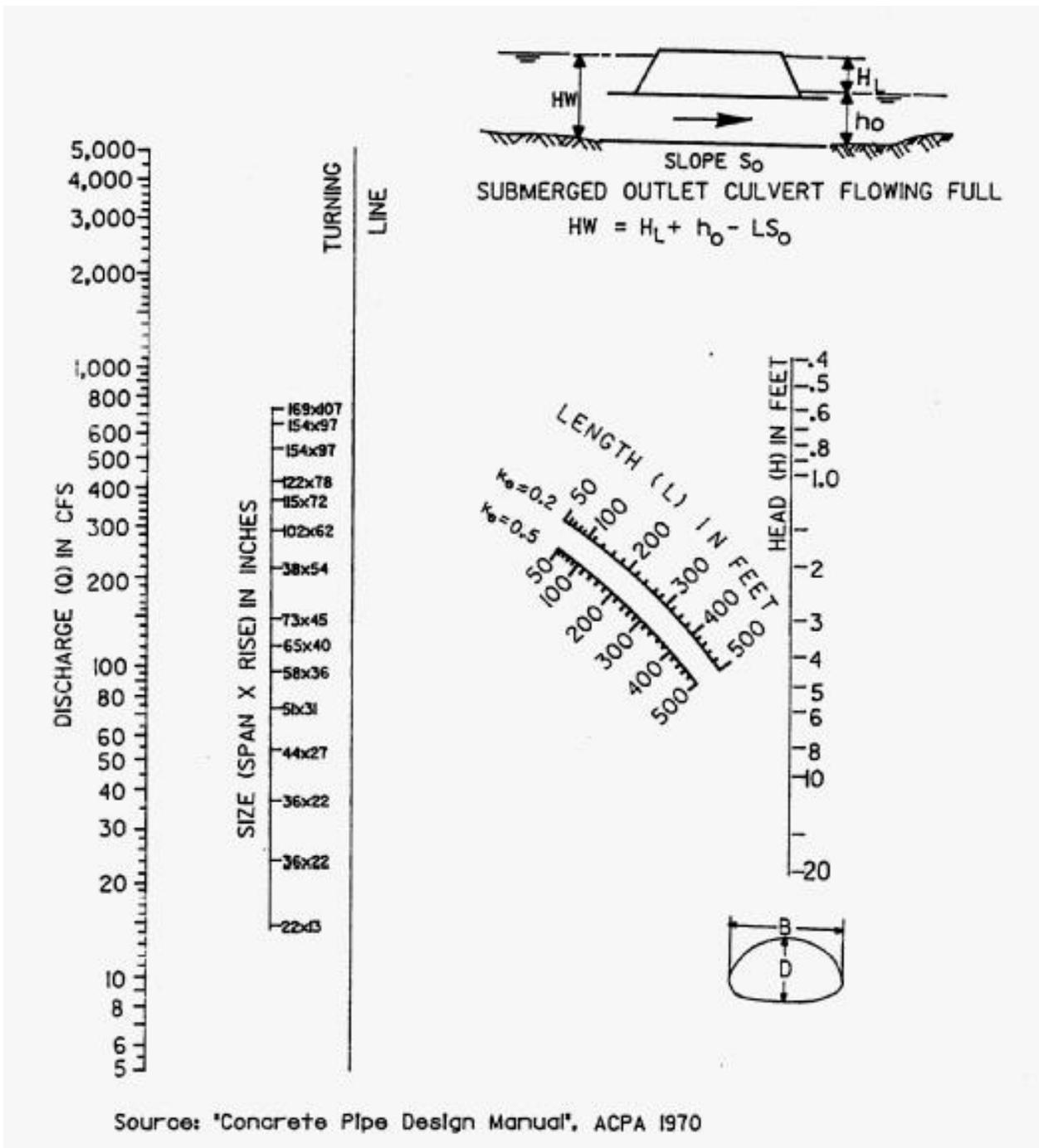
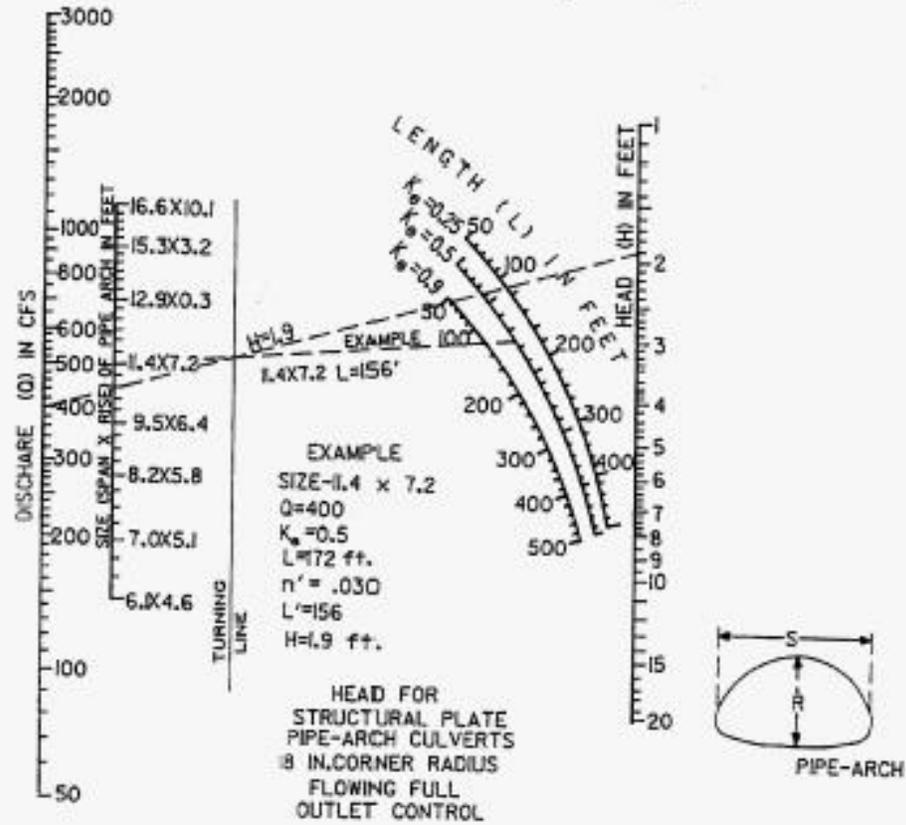
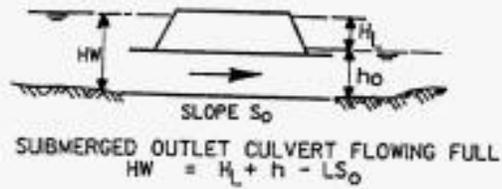


Figure 7-15: Outlet Control Nomograph, RCP Arch



OUTLET CONTROL. Head for structural plate pipe-arch culvert with 18 in corner radius with submerged outlet and flowing full. For 36 in. corner radius, use structure sizes with equivalent areas on the 18-in. corner radius scale.

Length Adjustment for Improved Hydraulics

Pipe-Arch Size in Feet	Roughness Factor		Length Adjustment Factor $\left(\frac{n'}{n}\right)^2$
	Curves based on n	Actual n'	
6.1 x 4.6	.0327	.0327	1.0
8.1 x 5.8	.0321	.032	1.0
11.4 x 7.2	.0315	.030	0.907
16.6 x 10.1	.0306	.028	0.837

Source: "Handbook of Steel Drainage & Highway Construction Products", AISI 1971

Figure 7-16: Outlet Control Nomograph, SPP Arch

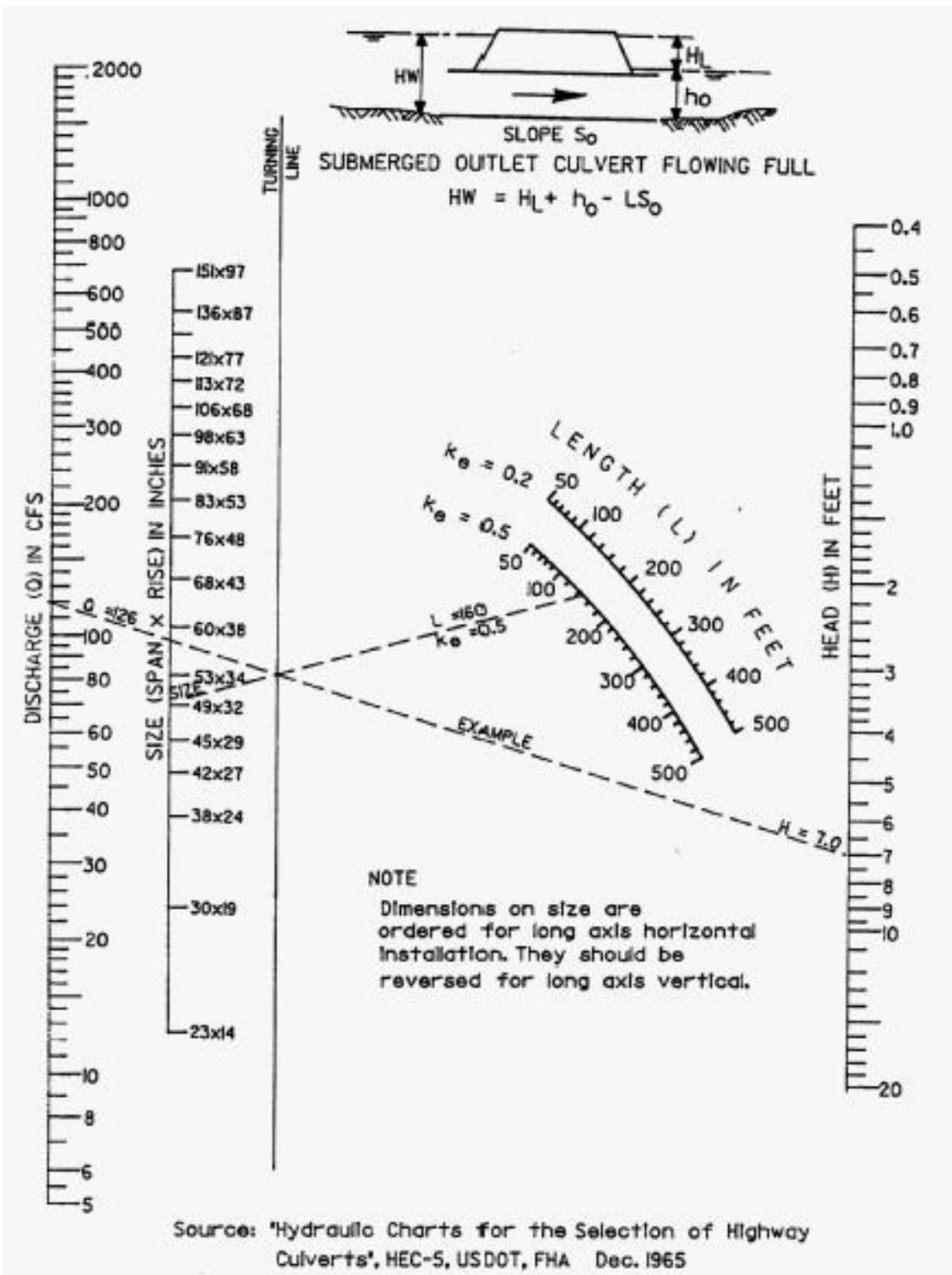


Figure 7-17: Outlet Control Nomograph, RCP Elipse

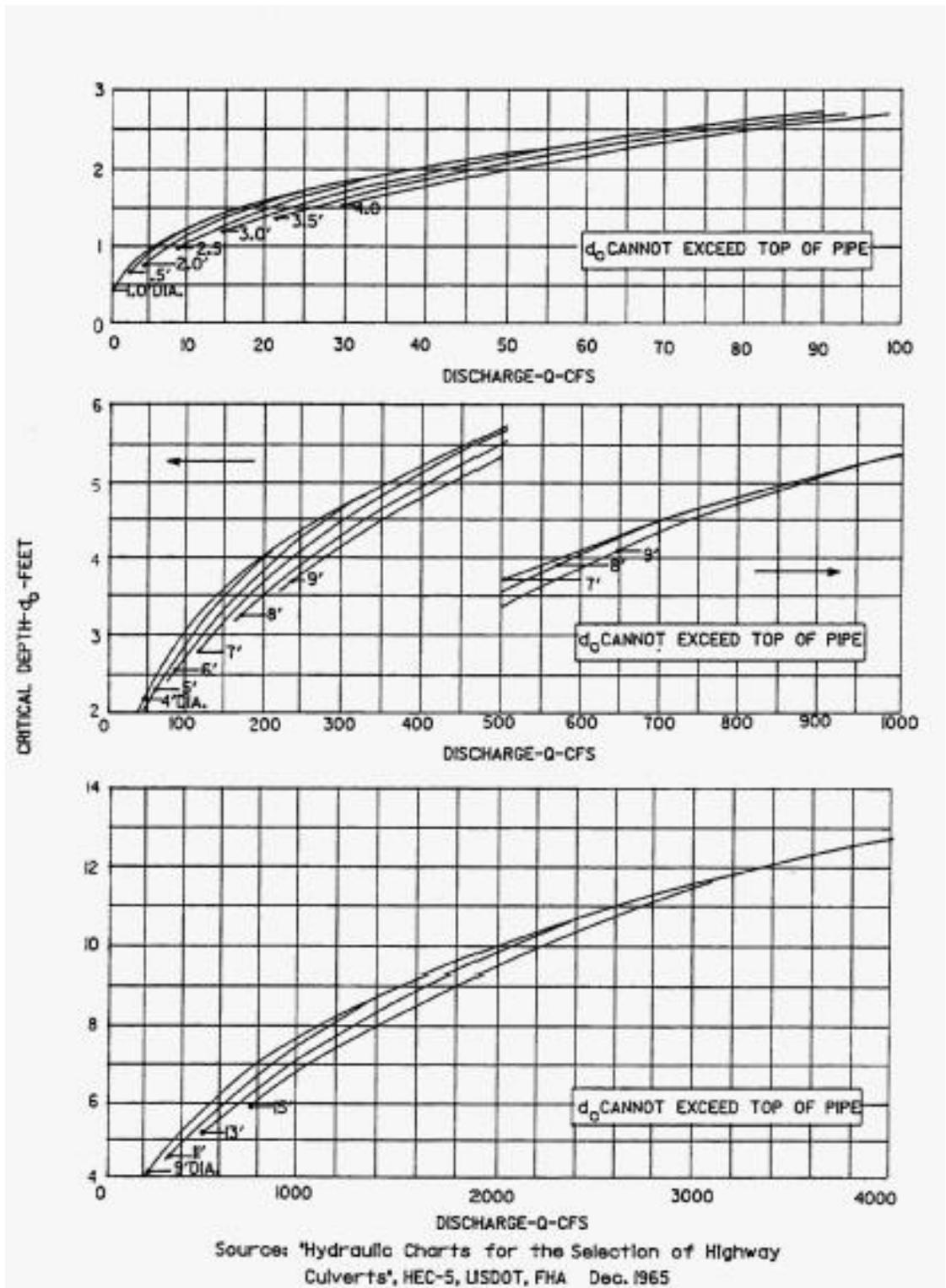
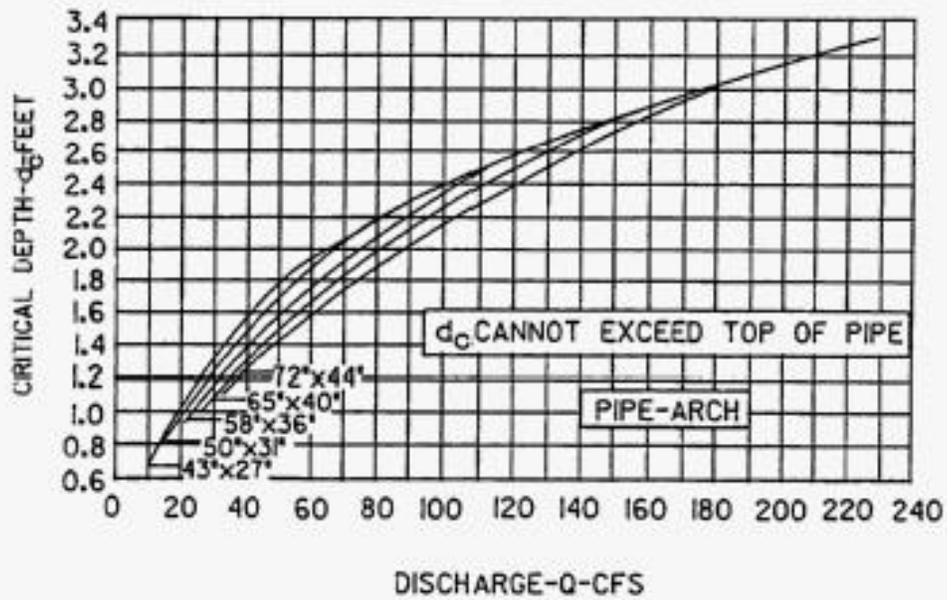
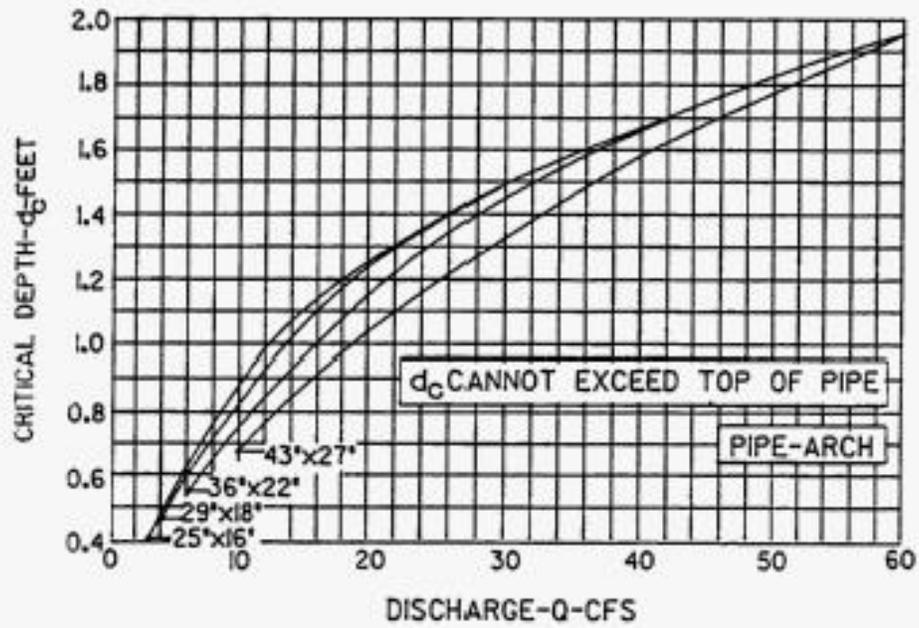


Figure 7-18: Critical Depth Curves, Circular Pipe



Source: "Handbook of Steel Drainage & Highway Construction Products", AISI 1971

Figure 7-19: Critical Depth Curves, CSP Arch

Source: Concrete Pipe Design Manual, ACPA 1970

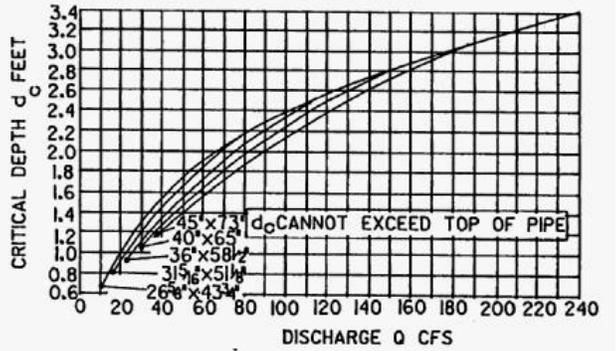
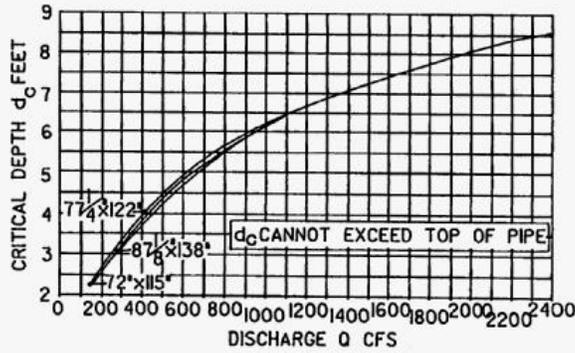
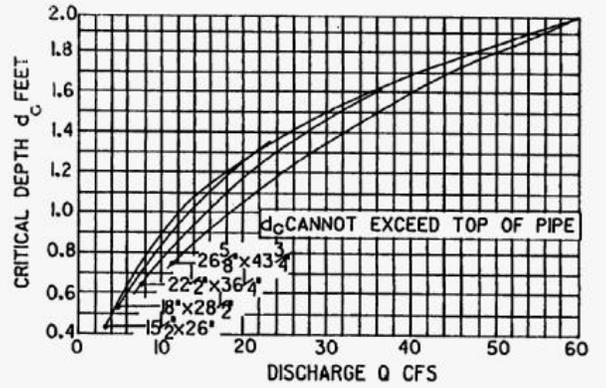
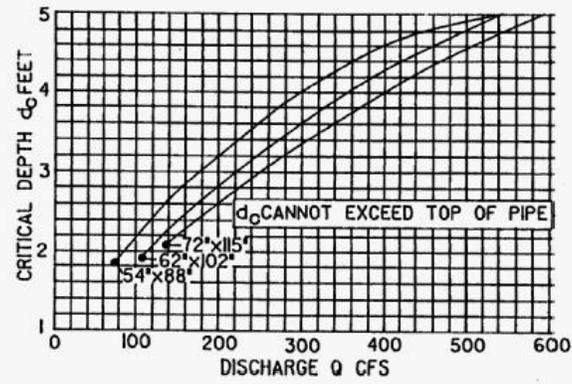
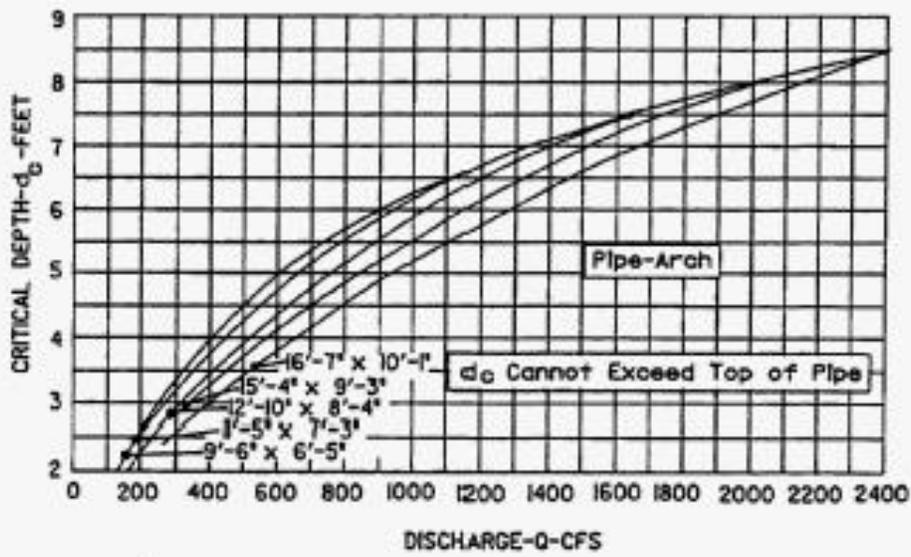
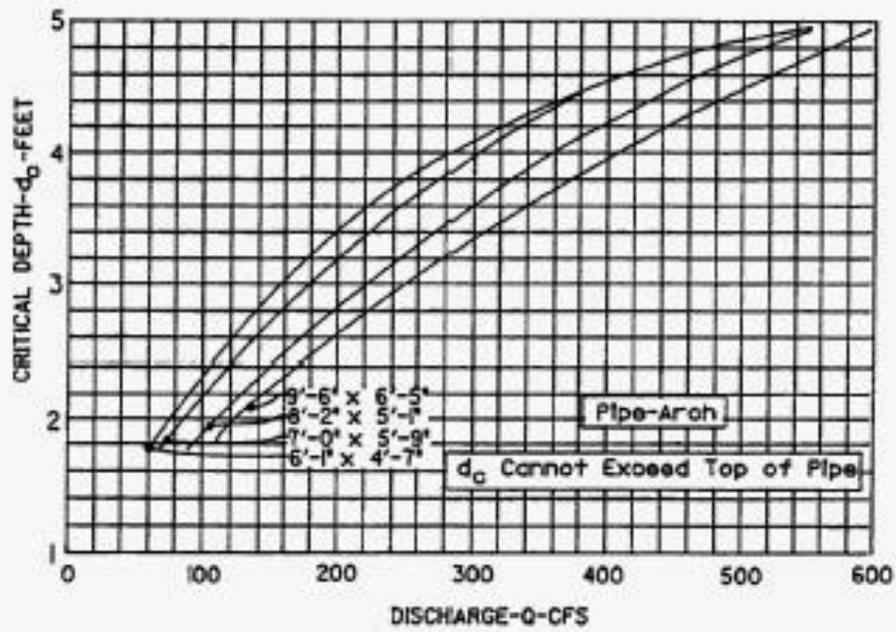
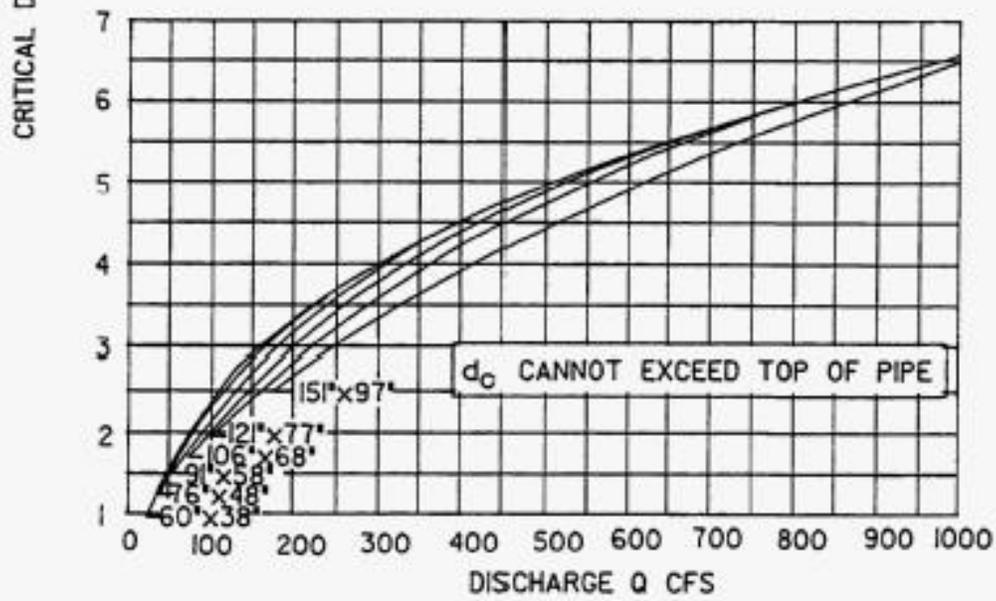
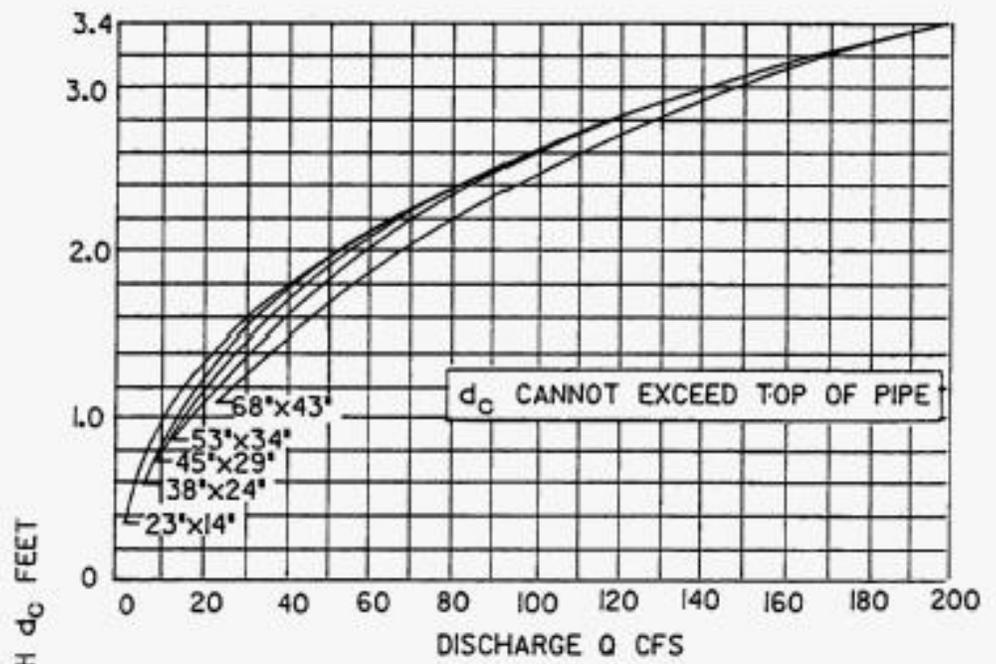


Figure 7-20: Critical Depth Curves, RCP Arch



Source: "Handbook of Steel Drainage & Highway Construction Products", AISI 1971

Figure 7-21: Critical Depth Curves, SSP Arch



Source: 'Concrete Pipe Design Manual', ACPA 1970

Figure 7-22: Critical Depth Curves, RCP Ellipse

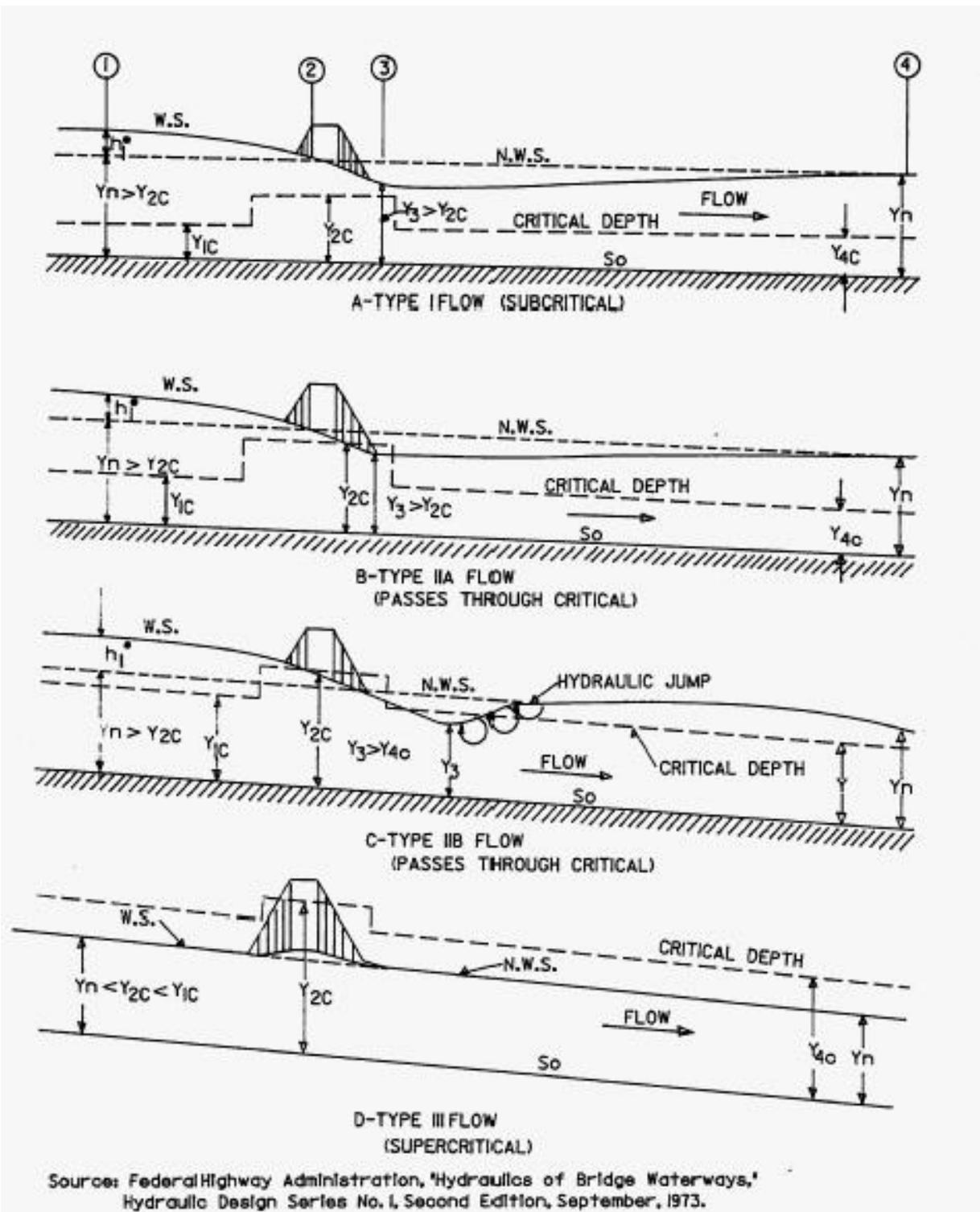


Figure 7-23: Types of Flow for Bridge Design

FIGURES FROM SECTION 8

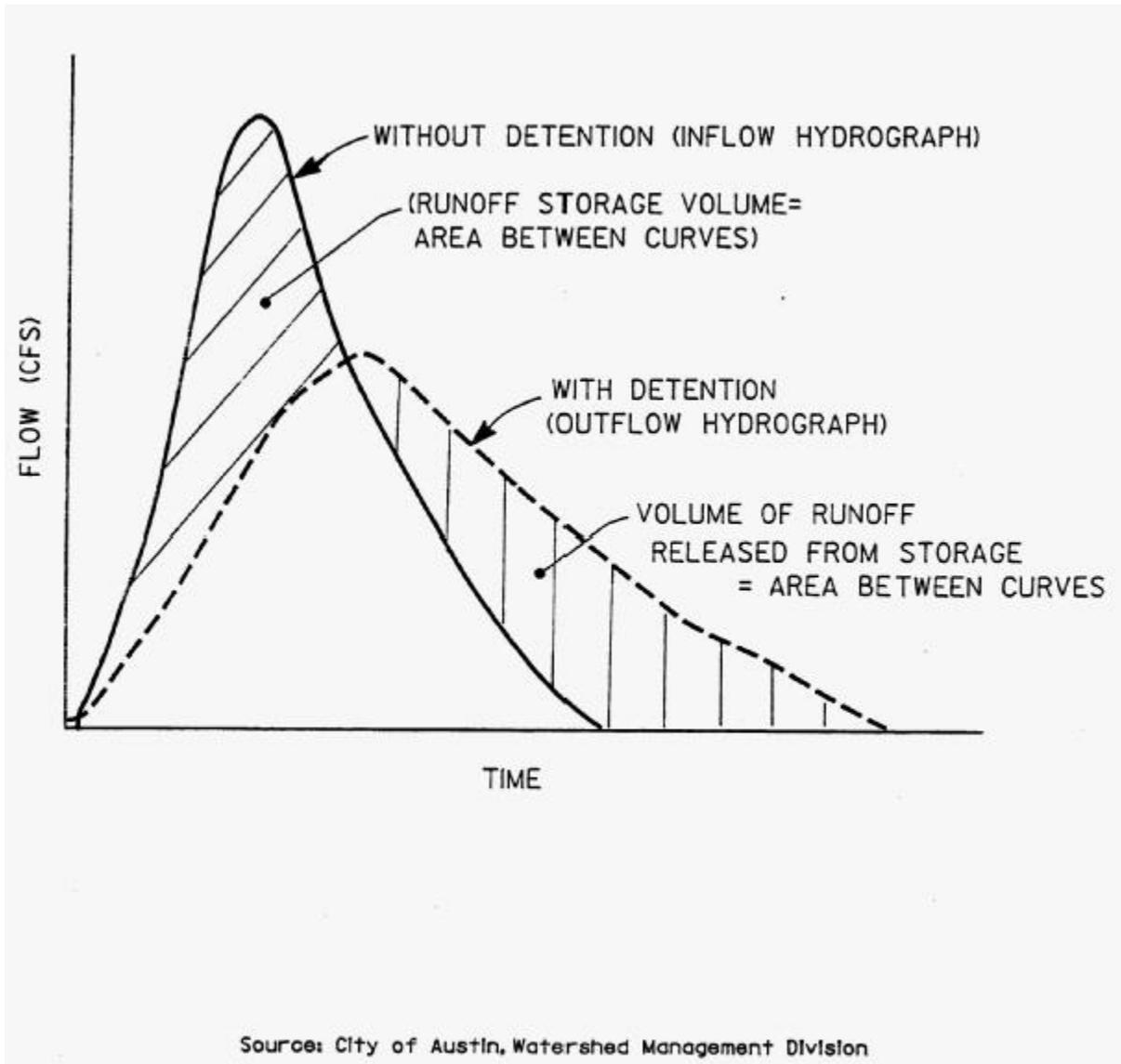


Figure 8-1: Concept of Detention Pond

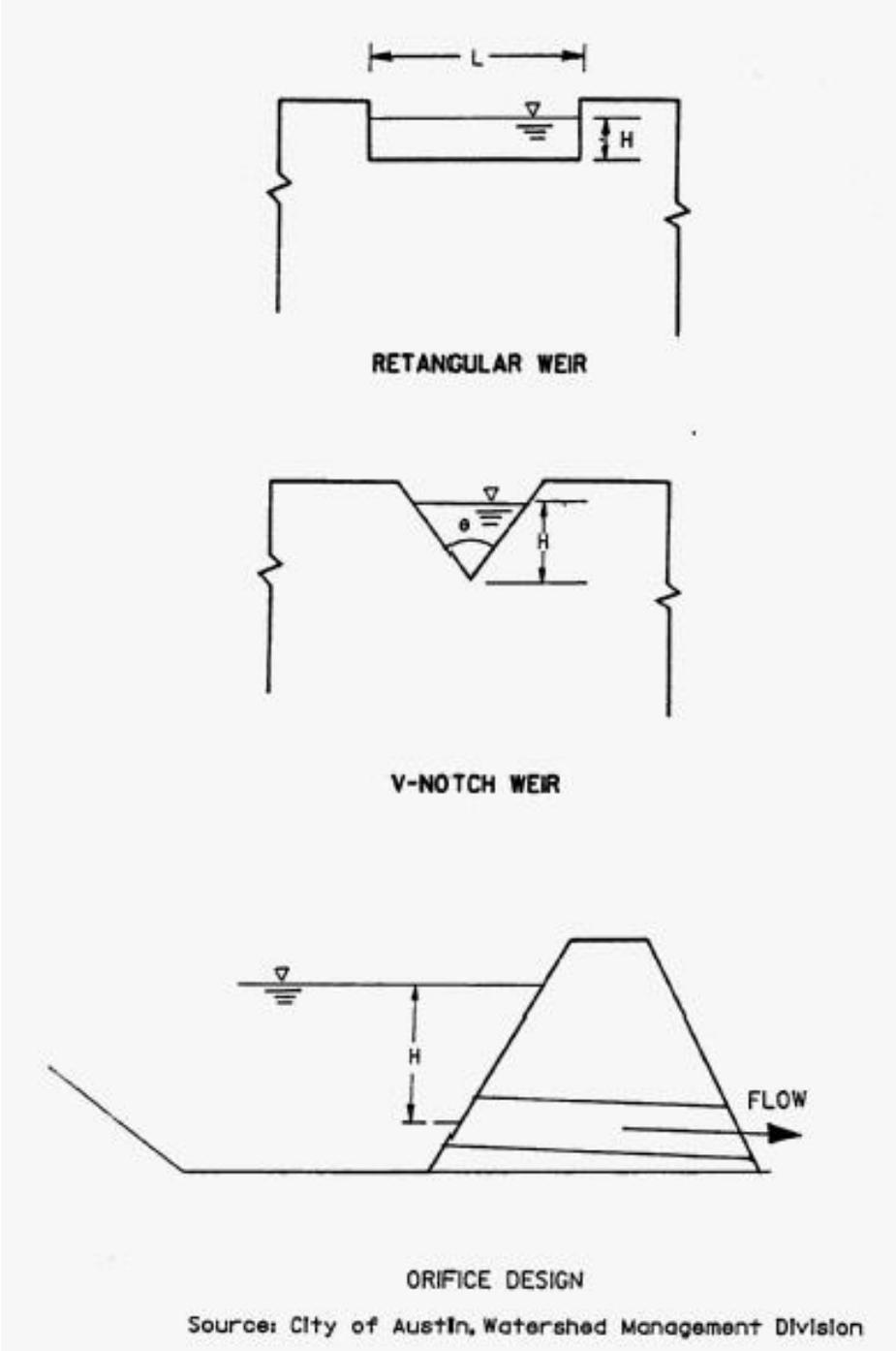


Figure 8-2: Weir and Orifice Flows